

Final Report to the
California Air Resources Board
(Research Contract A7-141-30)

THE IMPACT OF SULFUR DIOXIDE
ON A PROCESSING TOMATO STRESSED
WITH CHRONIC AMBIENT OZONE

R. J. Oshima, Plant Pathologist, CDFA
Statewide Air Pollution Research Center
University of California, Riverside, CA
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ABSTRACT

This study was designed to identify growth and yield responses of VF 145B-7879 processing tomato plants from ambient ozone and varying SO₂ exposures. The definition of possible interactions between the two gases was of greatest interest. A 3 x 3 factorial Anova design was therefore used to detect potential interactive responses.

Only sulfur dioxide exposures significantly affected yield reduction in this study. Both the ozone and O₃ x SO₂ terms were not significant in the Anova analysis. When the O₃ x SO₂ interaction term was partitioned to further scrutinize possible interactive effects, only a single complex interaction was weakly significant. The SO₂ quadratic-O₃ quadratic term was statistically significant (.05 level) but questionable in biological terms because of the nonuniformity of yield data in the two SO₂ treatments.

Intermittent SO₂ exposures of 10 and 20 pphm reduced marketable yields (weight of red and breaker fruit) of tomato by 16 and 20%, respectively. However, there was no statistical basis to separate the 16 and 20% reductions and they must be regarded as equivalent. SO₂ exposures did not influence fruit quality parameters (e.g., pH, pulp color).

Ozone did not influence tomato yield or quality in the factorial design, but foliar injury was observed in plants exposed in chambers to 25% filtered to 75% nonfiltered ambient air. Commercial yields from ambient plots, not enclosed in exposure chambers and independent of the factorial design, were reduced 66% when compared to the 100% filtered ambient air treatment. Plant dry weight, fruit pulp color and fruit size were also deleteriously influenced in ambient plot tomatoes. The ambient ozone dose during this study was 11,671 pphm-hrs. In Riverside, characterized by high ambient ozone and low SO₂ levels, the three highest ambient SO₂ and ozone one-hour average concentrations were 5, 6 and 8 pphm and 23, 27 and 28 pphm, respectively.

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CONCLUSIONS

Adverse effects of ozone in the the total oxidant complex in ambient air were detected only on the ambient air treatments where tomato plants were grown outside the Teflon covered chambers. The reduced commercial yield of 66%, reduced fruit size and plant dry weight may be attributed largely to the total ozone dosage of 11,671 pphm-hrs but it should be recognized that other factors unknown to us may have played an important role in the plant response. The dosage (concentration x time) of ozone was by design considerably less in the chambers than in ambient air and the peak concentrations were also lower with correspondingly lower hourly averages. On three dates reported in Table 16, one-hour ambient concentrations were 27, 23 and 28 pphm, respectively, while none of the chambers exceeded 17 pphm. The possibility that peak concentrations may have equal or greater influence on plant response than total dose must be considered.

The limitation of evaluating adverse plant response to the ambient treatment may also be related to differences in the chamber environment compared to the nonenclosed treatment. Air temperatures were comparable between these treatments but the mean relative humidity was less outside the chambers. Although it was concluded that photosynthetically active radiation transmission into the chambers was not a limiting factor, the fact that the mean flux for the ambient treatment was about 15% greater than the mean flux in the chambers may have influenced plant response to the ozone treatment.

Intermittent exposure to 10 and 20 pphm SO_2 decreased commercial yield. The fumigated levels were substantially higher than ambient SO_2 levels which could be characterized by the three highest one-hour values of 5, 6 and 8 pphm. The plant response to SO_2 treatment in these experiments should not be compared directly with the federal secondary standard.

The federal standard is based on a 3-hour average and the treatments in this experiment were 10 or 20 pphm for 6 hours on 5 successive days with at least 4 instances when the treatment continued for 24 hours. However, it should be noted that concentrations (40 pphm) during this experiment did not exceed either the primary or secondary federal SO₂ ambient air quality standards.

RECOMMENDATIONS

Further studies with VF 145B-7879 tomato should be run to more clearly define the response of this cultivar to SO₂ exposures. This particular cultivar was selected because of its importance to the tomato industry of California but studies with other cultivars should be run since the genetic variability of tolerance to ozone is well-known.

Future experiments with VF 145B-7879 tomato should include a treatment with 100% nonfiltered air within the Teflon chambers. Such a treatment would help to substantiate the finding reported here that a marked decrease in yield and plant growth was truly due to the ozone dosage or concentration and was not unduly influenced by the chambers. Experiments with 100% nonfiltered air would also help to determine if periodic peak concentrations exceeding about 20 pphm are critical in the production and growth reduction responses. It may well be that plant response was related as much or perhaps more to the incidents during a particular stage of growth when ozone exceeded some critical concentration than to the dose during the growing season.

The range of experimental parameters used in factorial designs should encompass peak concentrations and/or dosages which insure a measurable response to make the design effective for analysis. Experiments of the type reported here should have one treatment of ozone within the chambers that would assure measurable reduced growth and production or reduced fruit

quality even though the focus is on determining the response to realistic dosages. If it is unlikely that ambient concentrations or dosages will be sufficient to produce such response, the addition of synthesized ozone at intervals should be considered.

SUMMARY

The basic 3 x 3 factorial design using 100, 75 and 50% filtered to nonfiltered ambient air and 0, 10 and 20 pphm SO₂ with two replications of each treatment was used to study the response of VF 145B-7879 tomato plants to SO₂ and ozone. This design was used for Factorial Analysis of Variance of the response data.

To define the ozone dose response, results from the factorial design were supplemented by data from two replicates which received 25% filtered to 75% nonfiltered ambient air and two ambient air treatments that were not enclosed in chambers for the regression design.

Significant results obtained from the study included:

1. Ozone type injury to foliage was observed only on the plants in 25% filtered to 75% nonfiltered ambient air and on plants growing outside chambers in ambient air.
2. In the factorial design experiment no oxidant (ozone) effect on tomato plants was detected.
3. Fumigation with 10 and 20 pphm SO₂ significantly reduced commercial yield but there was no statistically significant difference between the 10 and 20 pphm treatments.
4. Ambient air treatment of plants growing outside the Teflon covered chambers receiving the highest ozone exposure had a reduced commercial yield, reduced number of red and breaker tomatoes, reduced pulp color below acceptable canning standards and reduced plant dry weight. Thus, the crops would have been a total loss to a grower.

I. INTRODUCTION

This study was designed to determine yield and quality responses of a commercial variety of processing tomato to ozone and SO₂ exposure and define possible interactions between the two gases. The experiment was conducted in an ambient fumigation facility which has been documented to be comparable to the ambient environment (5). Processing tomatoes represent an economically important crop grown throughout California, having a cash value of \$336,951,000 in 1978. Ozone levels were selected to represent the low to moderate ambient levels in production areas.

Ozone and SO₂ have been reported to interact to produce both antagonistic and synergistic foliar injury responses (3, 6, 7). The ozone x SO₂ interaction has also been demonstrated in terms of reduced biomass and yield on red kidney bean (4). However, the character of the interactive responses with foliar injury and yield conflicted. Red kidney bean foliar injury has been described as antagonistic with an ozone/SO₂ mixture (2) while yield responses were synergistic in a different study. The lack of correlation between foliar and yield responses therefore provided little to explain combined gas effects.

This experiment utilized a 3 x 3 factorial anova design replicated twice with three levels of ozone (100, 75 and 50% filtered to 0, 25, and 50% nonfiltered ambient air by volume) and three levels of SO₂ (0, 10 and 20 pphm). Two 25% filtered treatments and two ambient plots were also incorporated in the study so that regression analyses could be used as a second method of data analysis. In all, 20 chambers and two outside plots were used.

II. MATERIALS AND METHODS

Experimental Design

Two experimental designs were incorporated into this experiment:

1. The basic design was a 3 x 3 Factorial Analysis of Variance (Anova) using 100, 75 and 50% filtered to 0, 25 and 50% nonfiltered ambient air by volume and 0, 10 and 20 pphm SO₂ with two replications of each treatment.
2. A regression design using plant response at 100, 75, 50, and 25% filtered to 0, 25, 50 and 75% nonfiltered ambient air and at ambient air (outside plots) was also used to determine the ozone dose-response of VF 145B-7879 processing tomatoes. This design incorporated the 100, 75 and 50% filtered treatments of the preceding Anova design.

Ambient Fumigation Facility

An ambient fumigation facility constructed in 1977 under ARB contract A6-162-30 was used for the experiment.

1. General Schematic (Figure 1)

The facility consists of 20 Teflon covered exposure chambers divided into two replicate 10-chamber sets. Each set of chambers is connected to a common air handling system, consisting of ambient and filtered ducts. An instrument enclosure is centrally located between chamber sets to minimize sampling line lengths.

2. Air Handling System (Figure 2)

This system consists of two sets of two backward-curved blowers powered by 2 H.P. 220 V motors. Each set consists of a filtered (three-2' x 2' x 8" activated carbon filters) and an unfiltered blower, central underground plenums of 12" PVS (polyvinyl-coated steel spirallock pipe), and 6" PVS pipes with butterfly valves leading to each of 10 chambers. All PVS pipe, electrical, and water lines, and butterfly valves are underground.

Figure 1. General Schematic of Fumigation Facility

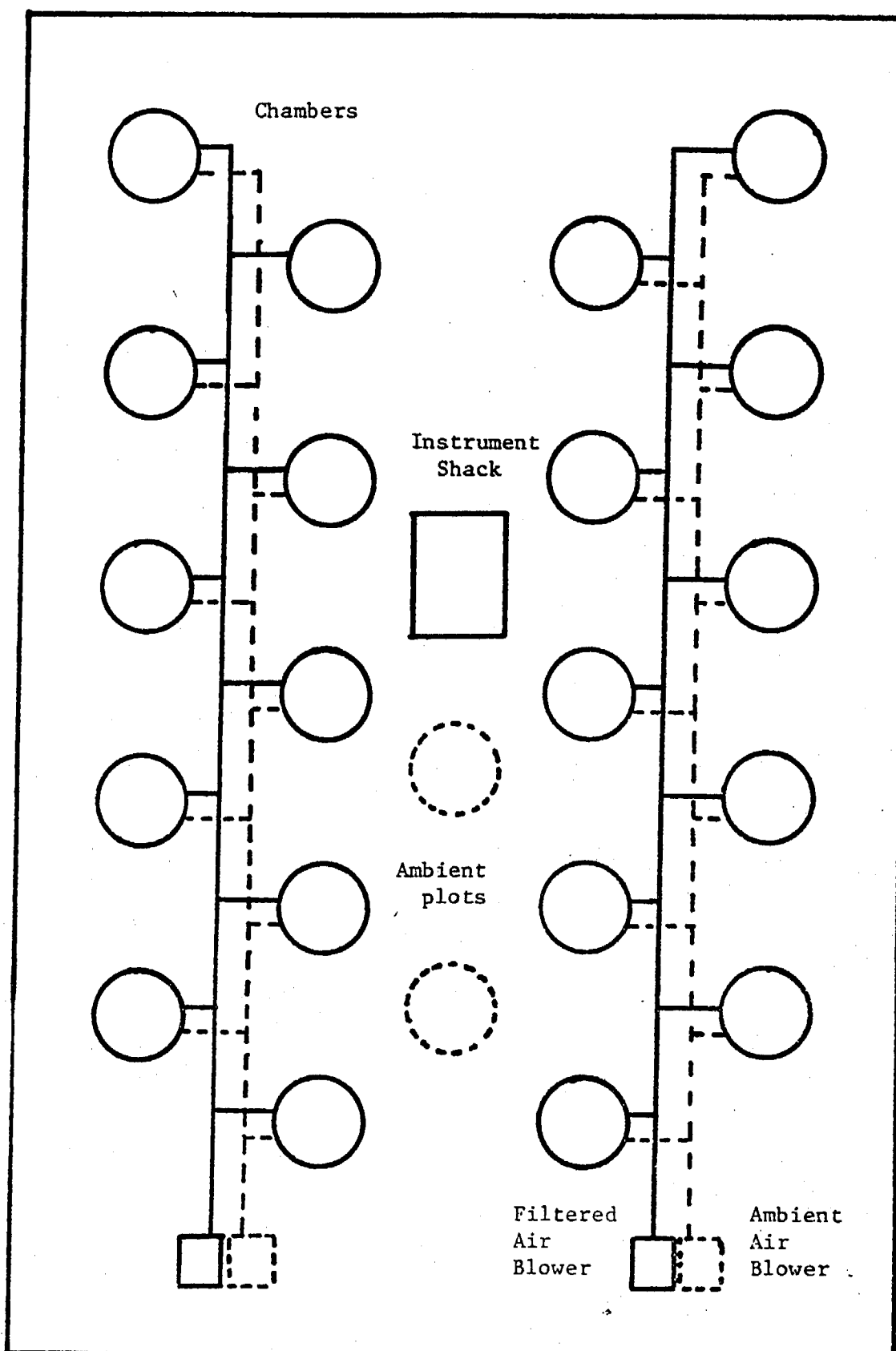
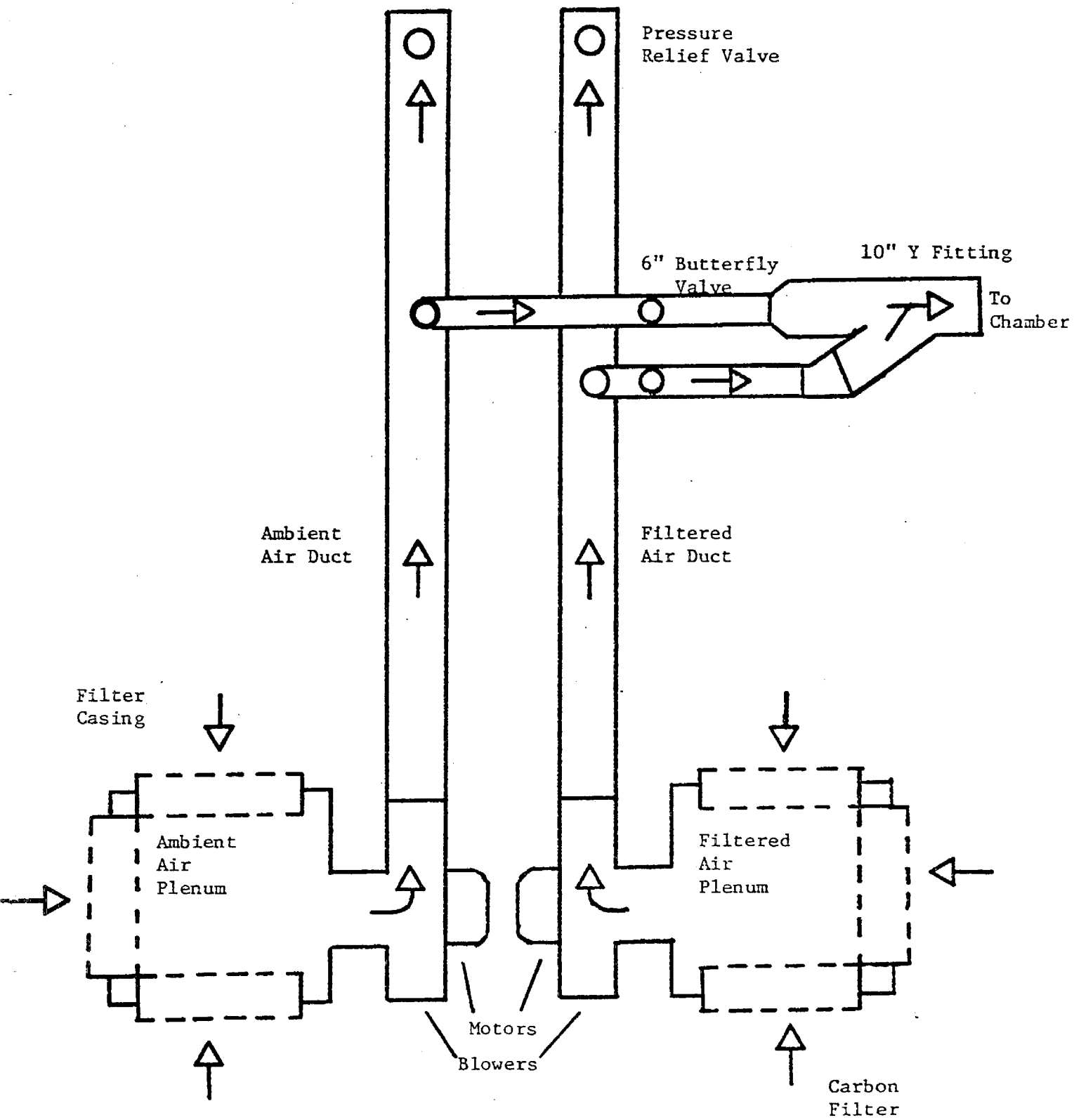


Figure 2. Detail of Air Handling System for Fumigation Chambers



The proportion of filtered to ambient air going to each chamber is controlled by the 6" butterfly valves. A comparison of replicate 0% filtered chambers with ambient ozone indicated that 17 to 21% of the ozone was lost in the air handling system.

3. Exposure Chambers (Figure 3)

The exposure chambers are a modification of the constant-stirred reactor (8) designed by Rogers, USDA, North Carolina State University, Raleigh, North Carolina. Each chamber consists of a 7' x 7' PVC schedule 80 frame bolted to a concrete ring. A 5 mil FEP Teflon envelope is suspended from the uppermost ring and anchored to the concrete with a 1/2" PVC ring. A small 1/120 H.P. shade pole 110 V motor is mounted at the apex of the PVC frame and anchors the uppermost portion of the Teflon envelope. An extension shaft from the motor protrudes through the Teflon envelope and supports a 6-blade impeller which rotates at 60 rpm. The mixture of filtered and nonfiltered air enters the chamber via a 10" PVS underground duct which then extends 5 ft vertically and directs the air stream directly at the impeller. Chamber exhaust is vented through a 10" PVS "U" tube directly into the atmosphere.

4. Fumigant Monitoring System (Figure 4)

Seventy-ft of 1/4" FTE Teflon lines run from each chamber. The air sample is pulled through a 3-way Teflon solenoid valve on each sample line to an exhaust manifold. An electrical control box regulates solenoid activation. Once activated, the solenoid valve diverts the flow to a sampling manifold from which the ozone and SO₂ instruments sample. This system continually pulls about 30 liters/min through each sampling line. Different chambers can therefore be monitored with a minimal lag time for

Figure 3. Diagram of Chamber Showing Structural Components
Chamber dimensions are 7' x 7'.

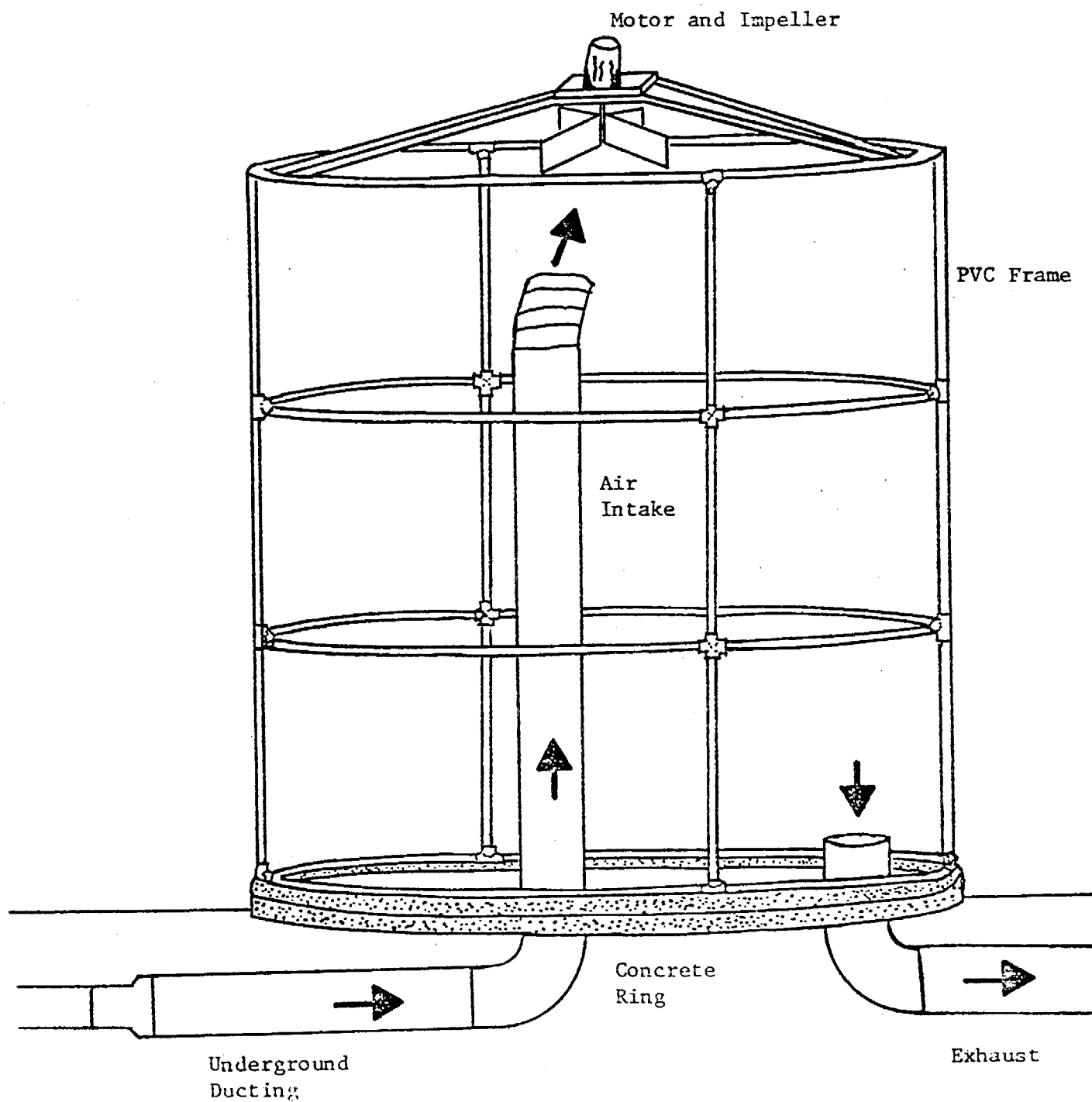
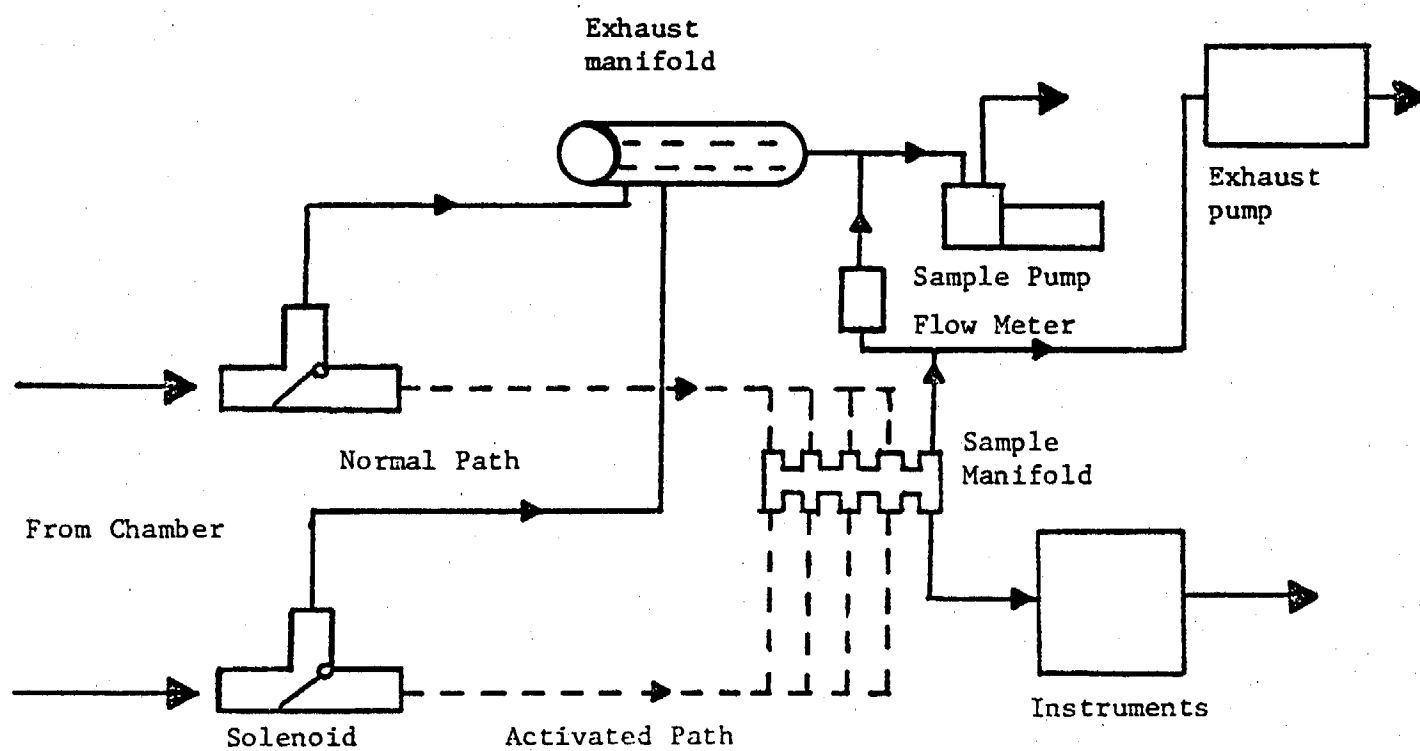


Figure 4. Flow Diagram of Gas Sampling System



purging the sampling manifold. All gas lines, solenoids and sampling manifolds are Teflon. All other valves, connectors and fittings are stainless steel. The entire sampling system, exclusive of the sampling lines, electronic control box and pumps, is contained in an insulated, thermally regulated box kept at 100°F.

Ozone was monitored by 2 Dasibi Model 1003-AH ozone monitors which use an ultraviolet absorption method for detection. Sulfur dioxide was monitored by 2 Thermoelectron Model 43 SO₂ analyzers which used a pulsed fluorescence method of detection.

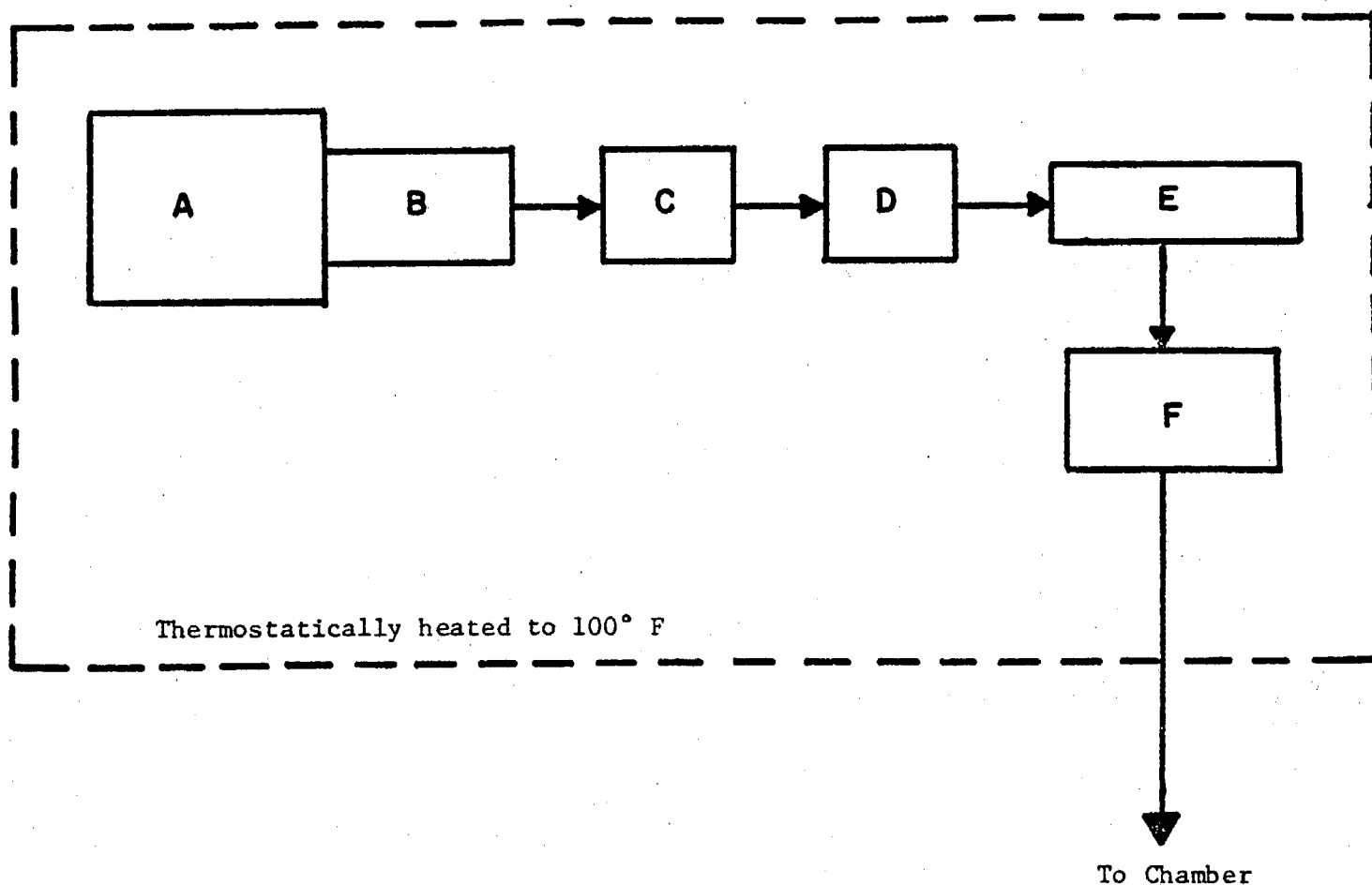
Ozone calibrations were conducted using an additional Dasibi ozone monitor as a transfer standard. This calibration instrument was verified at the ARB facility in El Monte, California by ultraviolet photometry and kept solely as a calibration standard for the Statewide Air Pollution Research Center.

The Thermoelectron Model 43 SO₂ analyzers were calibrated at the start and completion of the experiment using a Monitor Laboratories calibrator with a permeation tube. The calibrations were then verified using a known gas standard of SO₂ in nitrogen.

5. SO₂ Dispensing System (Figure 5)

The SO₂ dispensing system consists of 10 independent SO₂ generators housed in insulated, heated 40 gallon trash cans. Each generator contains a 6.7 liter tank of liquid SO₂ (99.8%), a pressure regulator, a 7 μ in-line filter, a Teflon solenoid valve, a 29 inch length of .005 inch I.D. stainless steel capillary tubing, and a manual shut-off valve. All fittings and tubing are stainless steel. The SO₂ flow is diverted into the exposure chamber inlet duct to be diluted before entering the exposure chamber.

Figure 5. Flow Diagram for Sulfur Dioxide Dispensers
The flow of SO_2 starts at the tank (A) and continues through the regulator (B), a solenoid (C), a $7\ \mu$ filter (D), a capillary tube (E), and through a shut-off valve (F) to the chamber.



Plant Selection and Cultivation

Three VF 145B-7879 tomato seeds were planted in each of 500 molded peat pots on April 27, 1978. Seedlings were thinned to a single most uniform plant per pot and grown in a carbon-filtered greenhouse until ready for transplanting. One hundred and seventy-six of the most uniform individuals were transplanted into 15-gallon containers within the 20 Teflon exposure chambers and 2 ambient plots on June 1, 1978. Each 15-gallon container was filled with a uniform soil mix (Table 1) and was buried in the ground to maintain ambient soil temperature.

Table 1. Constituents of Experimental Soil Tabulated per Cubic Yard of Mix.

Soil	14	ft ³
Canadian Peat Moss	7	ft ³
Redwood Shavings	7	ft ³
Single Super Phosphate	2.5	lbs
KNO ₃	4.0	oz
K ₂ SO ₄	4.0	oz
Dolomite Limestone	3.75	lbs
Oyster Shell Lime	1.50	lbs
Micronutrients		
Cu	30	ppm
Zn	10	ppm
Mn	15	ppm
Fe	15	ppm

All treatments received the equivalent of 200 lb N fertilizer per acre in addition to the nutrients premixed into the soil. The fertilizer was added in the form of $\text{Ca}(\text{NO}_3)_2$, and represented a commercial rate of application. Irrigation was applied uniformly throughout treatments when irrometers measured 20 to 30 millibars vacuum. All irrigations were applied with a drip system, insuring uniform application rates and excellent soil dispersion.

Malathion was applied once during the experimental period to eradicate an infestation of grasshoppers in chamber 15. The infestation stemmed from eggs laid during the winter months when the Teflon envelopes were off. Immature grasshoppers were noted in only one chamber but all chambers were treated uniformly. This problem was corrected before it was a significant factor.

Soil Samples

Core samples were taken from each 15-gallon container and mixed thoroughly to form one composite sample for each treatment. Soil samples were then sent to a private laboratory for analysis of soluble sulfate levels. These data are presented in Table 18, page 68. Core samples were taken from each container at two depths (0-8 inches and 8-16 inches) to determine the level of soluble salts. The analysis was performed using the electrical conductivity method (1).

Harvest Procedures

Tomato plants were cut at soil level and put in individual 30 gallon plastic bags for transport to the laboratory. Each plant was then subdivided into fruit and vegetative biomass. A subsample of 10 fruit per

plant was collected for quality evaluation and the remainder were individually weighed, measured and evaluated for the following parameters:

1. color - red ripe, breaker and green
2. blemish - physical scars, insect predation, rot, sunburn, and overripe
3. height - measured from attachment to blossom scar
4. diameter - measured on a perpendicular axis from height
5. weight - weight of individual fruit
6. counts - the number of fruit in each color category

The following quality parameters were measured for marketable fruit:

1. soluble solids - indicative of sugar content
2. pH - indicative of acid content
3. pulp color - indicative of marketability

Analysis of the quality parameters were run on a puree of the fruit subsamples from all harvested plants in each chamber. Only red ripe and breaker fruit (commercial yield) were included since a strict limit of 2% green fruit is allowed commercially. The vegetative biomass was recorded after oven drying at 60-70°C for four days. These measurements were exclusive of fruit.

Exposure Schedule (SO₂)

The SO₂ exposure schedule for the experiment is summarized in Table 2. The original design utilized a schedule of exposures which were limited to six hours in duration. The presented schedule was agreed on after a misunderstanding caused a 24-hour exposure to be carried out.

Table 2. Sulfur Dioxide Fumigation Schedule for Treatment of VF 145B-7879 Tomato Plants.

Date	Start	End	Duration (Hours)	Date	Start	End	Duration (Hours)
6-6	1000 ^a	1600	6	7-13	0900	—	—
6-7	0900	1500	6	7-14	—	0900	24
6-8	0900	1500	6	7-17	0900	1500	6
6-9	0900	1500	6	7-18	0900	—	—
6-12	1000	1600	6	7-19	—	0900	24
6-13	0900	1500	6	7-20	0900	1500	6
6-14	0900	1500	6	7-21	0900	1500	6
6-15	0900	1500	6	7-24	0900	—	—
6-16	0900	1500	6	7-25	—	0900	24
6-19	0900	1500	6	7-26	0900	1500	6
6-20	0900	—	—	7-28	0900	1500	6
6-21	—	0900	24	7-31	0900	—	—
6-22	0900	1500	6	8-1	—	0900	24
6-23	0900	1500	6	8-2	0900	1500	6
6-25	0900	—	—	8-3	0900	—	—
6-26	—	0900	24	8-4	—	0900	24
6-27	0900	1500	6	8-7	0900	1500	6
6-28	0900	1500	6	8-8	0900	—	—
6-29	0900	1500	6	8-9	—	0900	24
7-5	0900	1500	6	8-11	0900	1500	6
7-6	0900	—	—	8-14	0900	—	—
7-7	—	0900	24	8-15	—	0900	24
7-8	0900	1500	6	8-16	0900	1500	6
7-10	0900	—	—	8-17	0900	—	—
7-11	—	0900	24	8-18	—	0900	24
7-12	0900	1500	6				

^aTime is recorded in Pacific Standard Time.

III. RESULTS

All tables and figures in this section are presented consecutively following the narrative, pages 35 to 68.

Foliar Injury

Foliar injury was only observed within chambers in the 25% filtered to 75% nonfiltered ambient treatment and in the two ambient plots. Only the most mature leaves on tomato plants in the 25% filtered treatments were affected. These displayed foliar chlorosis but no necrosis or upper surface stipple. The first observed injury on the 25% filtered plants was observed on July 26, 1978 (50 days after treatments were started). Plants in the ambient plots developed severe foliar injury. Chlorosis was observed in the ambient plots starting June 28, 1978 and rapidly progressed to necrosis and premature senescence of mature leaves. Significant defoliation and severe injury was observed on vines at harvest.

Anova Analysis

The table of means (Table 3, page 35) and table of doses (Table 4, page 37) summarize data used in the 3 x 3 factorial analysis of harvest parameters. Only doses >0 pphm were used in the actual analysis although doses with calculation thresholds are presented for comparison. Pollutant doses were calculated using the following dose expression:

$$\text{dose} = \sum_i (h_i - x) \quad \begin{array}{l} h_i = \text{hourly average for the } i\text{th hour} \geq x \\ x = \text{calculation threshold} \end{array}$$

Ozone doses were calculated using calculation thresholds of 0, 3, 5, 8, 10, 15 and 20 pphm (Table 4). The same ozone dose calculation with a 10 pphm calculation threshold has been utilized in the past (5). Harvest

variables include:

1. Total wt. red and breaker tomatoes (commercial yield)
2. Total no. red and breaker tomatoes
3. Total no. red tomatoes
4. Total wt. red tomatoes
5. Total no. breaker tomatoes
6. Total wt. breaker tomatoes
7. Total no. green tomatoes
8. Total wt. green tomatoes
9. Soluble solids
10. Pulp color
11. pH
12. Dry wt. plants

The following calculations were also included in the analysis:

1. % no. red tomatoes
2. % no. breaker tomatoes
3. % no. green tomatoes
4. % no. red & breaker tomatoes
5. % wt. red tomatoes
6. % wt. breaker tomatoes
7. % wt. green tomatoes
8. % wt. red & breaker tomatoes

An initial analysis was run to compare variability in main effects and interactions using the 7 subsamples within each chamber and to determine whether the greater degrees of freedom for subsamples could be used. The eighth plant in each chamber was not used in the analysis since it was

sacrificed to determine harvest dates.

<u>Sources of Variation</u>	<u>df</u>
Blocks (B)	1
Subsamples (R)	6
SO ₂ (S)	2
Ozone (O)	2
R x B	6
R x S	12
R x O	12
B x S	2
B x O	2
S x O	4
R x B x S	12
R x B x O	12
R x S x O	24
B x S x O	4
Error	24
Total	125

Mean squares were compared and tested using rules originally proposed by Bancroft and listed on page 266 of Sokal and Rohlf (9). F values calculated from the appropriate mean squares did not meet required values at $P \leq 0.75$. Variables tested using these rules did not comply with the necessary criteria and the greater degrees of freedom for the subsamples could not be used.

The following analysis was then adopted for use:

<u>Sources of Variation</u>	<u>df</u>
Blocks (B)	1
Ozone (O)	2
Linear (L)	1
Quadratic (Q)	1
SO ₂ (S)	2
Linear (L)	1
Quadratic (Q)	1
S x O	4
S _L O _L	1
S _Q O _L	1
S _L O _Q	1
S _Q O _Q	1
Error	8
Total	17

The following unequal interval orthogonal polynomial coefficients were calculated and included here as an aid if others wish to repeat the analysis reported above:

Linear	-1.974399	-0.2609	2.235299
Quadratic	1.671569	-2.819006	1.147438

Harvest Variables

1. Total weight of red and breaker tomatoes (commercial yield):

Ozone effect: No ozone effect was documented on the commercial yield of VF 145B-7879 processing tomatoes in the 3 x 3 factorial experiment when

a maximum of 50% ambient air was used (Table 5).

SO₂ effect: SO₂ caused a linear reduction in the commercial yield of VF 145B-7879 processing tomatoes (Table 5). The 20 pphm SO₂ treatment plants produced 20% less than the non-fumigated tomato plants but there was no difference in commercial yield between the 20 pphm and 10 pphm treatment plots.

SO₂ - O₃ interaction: A complex SO₂ quadratic-ozone quadratic interaction was significant even though the main interaction term was not (Table 5). A graphic representation of the interaction (Figure 6) indicated that high production in the 3243 pphm-hr ozone - 10 pphm SO₂ treatments produced this effect. This response was based on a single treatment effect.

2. Total number of red and breaker tomatoes:

Ozone effect: No ozone effect was detectable (Table 6).

SO₂ effect: A linear reduction in the number of red and breaker tomatoes was significant ($p < .05$) (Figure 7).

SO₂ and O₃ interaction: No interactions were significant.

3. Total number and weights of tomato fruit according to color categories (red, breaker and green):

Processing tomatoes may produce two distinct fruit sets in a season. The fruit sets are distinct and do not overlap in their maturing. The first set is normally ripe or in the final stages of ripening when the second set is hard green. The initial set would rot if the field harvest was delayed long enough to include the mature second fruit set. The first fruit set is therefore in almost all cases the commercial harvest.

The VF 145B-7879 processing tomato is normally harvested when 80% of the first fruit set is red ripe. This percentage is exclusive of the

hard green fruit in the second fruit set. One plant per chamber was sacrificed on August 21, 1978 to determine the red ripe ratio. The rate of 2% ripening per day was utilized to project chamber harvests from the ratios obtained on 21 August. Chamber harvests were conducted based on these projected dates, and are listed below.

<u>Chamber No.</u>	<u>Harvest Date, 1978</u>	<u>Chamber No.</u>	<u>Harvest Date, 1978</u>
1	8-24	12	8-25
2	8-25	13	8-23
3	8-23	14	8-23
4	8-23	15	8-31
5	8-31	16	9-1
6	9-1	17	8-31
7	8-31	18	8-28
8	8-28	19	9-1
9	9-1	20	8-28
10	8-28	A1	8-23
11	8-24	A2	8-23

A mean percentage of 87% red ripe at harvest resulted within a range of 83% to 94% red ripe.

The responses of the number and weight of red ripe tomatoes produced (Tables 7, 8) were equivalent to the analysis of the commercial yield and number of red and breaker fruit except for the interaction. The graphic representations (Figures 8, 9) also indicated the same responses.

The breaker fruit represented only a small fraction (16%) of the total fruit set of the plants. The anova analyses (Tables 9, 10) indicated several significant main effects and interactions for both the number and weight of breakers produced and the graphic representations (Figures 10,

11) clearly corroborated the existence of the interactions. Although the statistical significance of differences in the breaker responses are at times quite high, the biological values of these responses is negligible. Most breaker responses are completely masked by the greater numbers of red ripe fruit and their effect on the commercial harvest was minute.

There were no green fruit main or interactive responses to ozone or SO_2 .

4. Calculated percentages of red, red & breaker or green tomatoes in terms of number or weight:

None of the calculated variables were observed to be affected by SO_2 , ozone or interactive effects.

5. Pulp color:

The State of California regulates the degree of pulp color acceptable for canning tomatoes. Pulp color is measured on an Agtron colorimeter with a scale from 0 to 120 arbitrary units. Color ranges in intensity from a maximum of 0 to a minimum of 120 Agtron units. The state regulation requires an Agtron reading of 40 or less before harvested fruit are acceptable for processing.

SO_2 linearly decreased the intensity of fruit color in VF 145B-7879 processing tomato fruit (Table 11). The reduction in color of fruit pulp (increased Agtron number) was well within the acceptable Agtron range and would not influence the marketability of the commercial yield. The SO_2 effect can be observed at the low ozone dose in Figure 12.

6. pH:

A pH of 4.4 or less is necessary if tomato fruit are considered to be acceptable for processing by canners. Higher pH values do not suppress

bacterial spoilage and require longer processing time.

All pH values measured from fruit were below the 4.4 pH limitation. A few pH responses differed significantly (Table 12) but were based on commercially insignificant alterations in a minimal range of pH values. The range of mean values for the Anova analysis was only 4.13 to 4.26 pH units.

7. Soluble solids:

No effects of ozone, SO₂, or the combinations of both gases were detectable (Table 14).

8. Plant dry weight:

SO₂, ozone and the gas mixtures did not affect plant dry weights (Table 13). Mean weights of plants proved to be statistically different between blocks. No apparent reason for the block differences was evident.

Regression Analysis

Chamber replicate variables and ozone dose data are presented in the table of means (Table 14) and the table of doses (Table 15). All plant harvest variables and doses are presented but commercial yield (weight of red and breaker tomatoes) was the only biologically valid variable influenced.

The preceding Anova analysis indicated that ozone did not affect commercial yields of tomato plants exposed to ozone doses of 1530, 3243 and 5740 pphm-hrs. The 25% filtered to 75% nonfiltered ambient (average ozone dose 8268 pphm-hrs, Table 15) treatment not included in the design of the 3 x 3 factorial was included in a regression to determine the slope and compare it with the filtered treatment:

$$\text{Yield} = 3210.38 + .0207 (\text{dose}) \quad r = 8952^*$$

The addition of this point produced a positive slope of .0207 which is not statistically significant from zero and is indicative of no yield loss. A plot of the treatment means clearly substantiated this (Figure 13).

No regressions were calculated for the SO₂ main effect since only three points were available and the responses to the 10 pphm and 20 pphm treatments were statistically equivalent. The orthogonal polynomials in the Anova analysis indicated a strong linear response but a model of the functional response should be calculated from an additional experiment designed to achieve this.

Fruit Size Distribution Analysis

A fruit size distribution analysis of red and breaker fruit was undertaken utilizing five categories based on weight. Tomato fruit were sorted into the 25-gram categories and a frequency distribution generated. Fruit size distributions are presented in Figure 14.

Only the ambient plots (ozone dose 11,671 pphm-hrs) were observed to show a shift to smaller fruit. All but a few fruit were in the three smallest size categories. In contrast, all other treatments were found to have a similar size distribution without a significant shift towards smaller fruit.

Ambient and 25% Filtered Treatments

Ambient (11,671 pphm-hrs) and 25% filtered to 75% nonfiltered ambient air treatments (8268 pphm-hrs) were incorporated into the experiment to provide data for regression analysis. Unfortunately, no significant ozone yield responses were detected in the 25% filtered to 75% nonfiltered ambient air

treatment. This extended the lack of an ozone effect from the treatments used in the 3 x 3 factorial analysis to an ozone dose of 8268 pphm-hrs.

Ambient treatments provided the only discernible ozone effects in the experiment. The fruit size distribution analysis previously described was indicative of this. Also, significant reductions in weights of red and breaker tomatoes (commercial yield), number of red and breaker tomatoes, associated differences in the weights and numbers of fruit in the color categories, pulp color (not acceptable for canning by State of California standards), and plant dry weight were found using unpaired t tests with the 25% filtered to 75% nonfiltered ambient air treatments ($p < .05$). No regressions were conducted because of the lack of effect on other treatments. Regression analysis using only the 25% filtered to 75% nonfiltered ambient air and ambient treatments would be improper. The overall relationship of the ambient and 25% filtered to 75% nonfiltered ambient air treatments to the other treatments is depicted in Figure 15 for commercial yield. The functional relationship is the same for the other affected variables.

Environmental Analysis

The calibration of the environmental factors for the fumigation facility was checked before the initiation of the experiment. No significant deviations from the initial calibration carried out in 1977 (5) were observed. Environmental variables were monitored throughout the duration of the experiment.

1. Temperature: Chamber temperatures closely simulated ambient conditions. Chamber mean maximum temperatures for the experimental period were generally cooler than ambient with only a single chamber exceeding ambient by 0.5°F . Mean maximum temperatures ranged from 96.4°F to 101.2°F compared with a mean ambient maximum of 100.7°F . Chamber mean

minimum temperature ranged from 62.6°F to 63.4°F in contrast to an ambient mean minimum temperature of 59.4°F. Examples of chamber temperature variations are given in Appendix A.

2. Photosynthetically Active Radiation (PAR): Chamber transmission tests (Figures 16, 17, 18) were conducted on a randomly selected chamber before, during and after experimentation. The exposure chambers transmitted a mean of 86.8% of the available ambient PAR. PAR monitoring was carried out semicontinuously during the experimentation. Monitoring indicated that a mean flux of 1439 μ einsteins $m^{-2} sec^{-1}$ was available within chambers compared to mean of 1658 μ einsteins $m^{-2} sec^{-1}$ available in the ambient environment. Available light as measured by PAR was not considered to be a limiting factor influencing yields.

3. Relative Humidity: Mean relative humidity (RH) readings ranged between 60.9% and 54.7% in the chambers and were not significantly different at canopy heights. The RH readings were somewhat higher than the 51.3% and 44.2% ambient RH, as expected. Transpiration from the tomato plants and weekly irrigations within the chambers were probably responsible for the higher chamber RH.

All relative humidity readings were calculated from wet and dry bulb thermocouple data. Examples of chamber RH variations are presented in Appendix B.

4. Peak Chamber Ozone Concentrations: The peak ozone concentrations (highest one-hour average) for the fumigation facility and the associated ambient levels are listed in Table 16. These were taken from the highest monitored ozone days in the growing season.

5. Soil Analysis: The soil analysis before and after experimentation (Table 17) was carried out by the University of California Cooperative

Extension Laboratory at Riverside. The largest change in constituents occurred in the depletion of available nitrogen as nitrate. This was expected since the soil is rather sandy with excellent drainage and provided an excellent opportunity for leaching of the nitrates.

Sulfate analysis of soil from each chamber was quite variable (Table 18). The variability appeared to stem chiefly from sampling techniques since all samples were run without actual identification and two dummy samples of fresh soil were found to have exactly the same levels. No correlation with SO₂ treatments was observed with the SO₄ analysis. The soluble sulfate levels were all within a perfectly safe range for good tomato growth and production.

Soil salinity analysis revealed extremely low levels of soluble solids. The highest single reading was 1.50 millimhos/cm compared to a fresh soil level of 1.30 millimhos/cm. Salinity did not enter into the experiment as a significant variable.

Dose Calculations

Ozone doses were calculated using thresholds of 0, 3, 5, 8, 10, and 15 pphm. These doses are summarized in Table 15. The (SO₂) (O₃) doses were also calculated using O₃ pphm-hrs (for non-fumigated periods) + (SO₂) and (O₃) pphm-hrs (for fumigated periods). The resultant doses were as follows:

<u>Chamber</u>	<u>Dose</u>	<u>Chamber</u>	<u>Dose</u>
1	21,465	11	18,382
3	4,793	13	4,126
4	16,208	14	16,192
6	8,830	16	10,051
8	36,387	18	34,134
10	11,209	20	10,396

No regressions were conducted on the dependent variables since the only significant plant responses occurred in the ambient replicates or in the three point SO₂ treatment gradient.

Table 3. Mean of Data from Two Treatment Plots for All of the Tomato Plant Response Factors Measured in the 3 x 3 ANOVA Experiment (Page 1 of 2)

Filtered ambient air (%)	Level SO ₂	Total # red	Total wt. red (g)	Total # breaker	Total wt. breaker (g)	Total # green	Total wt. green (g)	Total # red & breaker	Total wt. red & breaker(g)	Pulp Color ^a	Soluble Solids
100	0	61.07	3077.18	3.71	175.3	13.71	528.35	64.78	3252.48	27.28	5.98
100	10	45.21	2219.98	7.71	423.99	24.57	941.48	52.93	2643.96	31.28	5.58
100	20	49.57	2603.97	5.0	220.24	24.35	952.14	54.57	2824.21	31.64	5.98
75	0	57.07	2989.89	5.85	292.37	15.78	544.62	62.85	3282.25	28.43	5.78
75	10	56.57	3026.56	7.57	448.10	12.07	449.78	64.14	3474.67	27.78	5.76
75	20	43.28	2319.09	6.28	328.48	25.14	966.02	49.56	2647.57	29.86	5.53
50	0	58.21	2862.34	8.0	411.11	19.35	791.73	66.28	3277.16	28.14	5.47
50	10	34.42	1803.95	6.0	291.78	32.43	1133.01	40.43	2095.73	29.35	5.54
50	20	44.07	2072.67	8.14	362.71	24.79	965.92	52.21	2435.38	31.21	5.61

^aAgtron units.

Table 3 continued (Page 2 of 2)

Filtered ambient air (%)	Level SO ₂	pH	Plant dry wt. (g)	% no. red	% no. breaker	% no. green	% no. red & breaker	% wt. red	% wt. breaker	% wt. green	% wt. red & breaker
100	0	4.26	193.4	77.87	4.73	17.39	82.60	81.49	4.65	13.85	86.15
100	10	4.18	189.3	48.71	10.06	30.58	69.42	63.53	11.9	24.56	75.44
100	20	4.13	195.95	62.47	6.48	31.04	68.96	68.91	6.06	25.03	74.97
75	0	4.18	199.45	73.26	7.46	19.27	80.65	78.63	7.67	13.7	86.3
75	10	4.21	176.2	74.33	9.96	15.71	84.29	77.17	11.46	11.37	88.62
75	20	4.25	181.05	59.43	8.55	32.01	67.99	65.37	9.22	25.40	74.59
50	0	4.20	186.6	68.47	9.40	22.12	77.96	70.78	10.13	19.08	81.01
50	10	4.20	166.8	48.38	8.24	43.38	56.62	56.64	9.00	34.35	65.64
50	20	4.19	218.7	57.14	10.53	32.33	67.68	61.14	10.74	28.11	71.88

Table 4. Calculated Dose of Ozone Using the Seven Designated Threshold Levels

Filtered ambient air (%)	Level SO ₂	Dose >0 pphm-hrs	Dose >3 pphm-hrs	Dose >5 pphm-hrs	Dose >8 pphm-hrs	Dose >10 pphm-hrs	Dose >15 pphm-hrs	Dose >20 pphm-hrs
100	0	1338.0	0.5	0	0	0	0	0
100	10	1403.5	1.0	0	0	0	0	0
100	20	1848.5	2.5	0	0	0	0	0
75	0	3136.0	482.0	65.0	0	0	0	0
75	10	3299.0	437.0	38.0	0	0	0	0
75	20	3295.5	492.0	63.0	0	0	0	0
50	0	5462.0	1814.5	650.0	68.5	6.5	0	0
50	10	5319.5	1915.5	742.0	94.0	11.0	0	0
50	20	6437.5	2306.5	955.0	138.0	21.0	0	0

Table 5. Analysis of Variance of Variable 1 - Wt. Red & Breaker Tomatoes

Source of Variation	df	SS	MS	F	Coefficient of variation
B	1	121914.300	121914.300	0.81	
O	2	855110.500	427555.300	2.84	
Linear	1	365877.300	365877.300	2.43	
Quadratic	1	489233.600	489233.600	3.25	
S	2	1394317.000	697158.400	4.63*	
Linear	1	1209319.000	1209319.000	8.04*	
Quadratic	1	184997.300	184997.300	1.23	
S x O	4	1225585.000	306396.300	2.04	
SL OL	1	84536.770	84536.770	0.56	
SQ OL	1	165375.100	165375.100	1.10	
SL OQ	1	956.395	956.395	0.01	
SQ OQ	1	974716.500	974716.500	6.48*	
Error	8	1203869.000	150483.700		13.5%
TOTAL	17	4800796.000			

Combination	Count per Mean	Subclass			Means
		B	S	O	
B	9				
		1	0	0	2799.19
		2	0	0	2963.79
O	6				
1530 pphm-hr		0	0	1	2906.89
3243 pphm-hr		0	0	2	3134.83
5740 pphm-hr		0	0	3	2602.76
S	6				
0 pphm		0	1	0	3270.63
10 pphm		0	2	0	2738.12
20 pphm		0	3	0	2635.72
S x O	2				
		0	1	1	3252.48
		0	2	1	2643.96
		0	3	1	2824.21
		0	1	2	3282.25
		0	2	2	3474.67
		0	3	2	2647.57
		0	1	3	3277.16
		0	2	3	2095.73
		0	3	3	2435.38

* = significance at .05

Figure 6. Effect of Ozone and SO₂ on the Total Weight of Red & Breaker Tomatoes (grams)

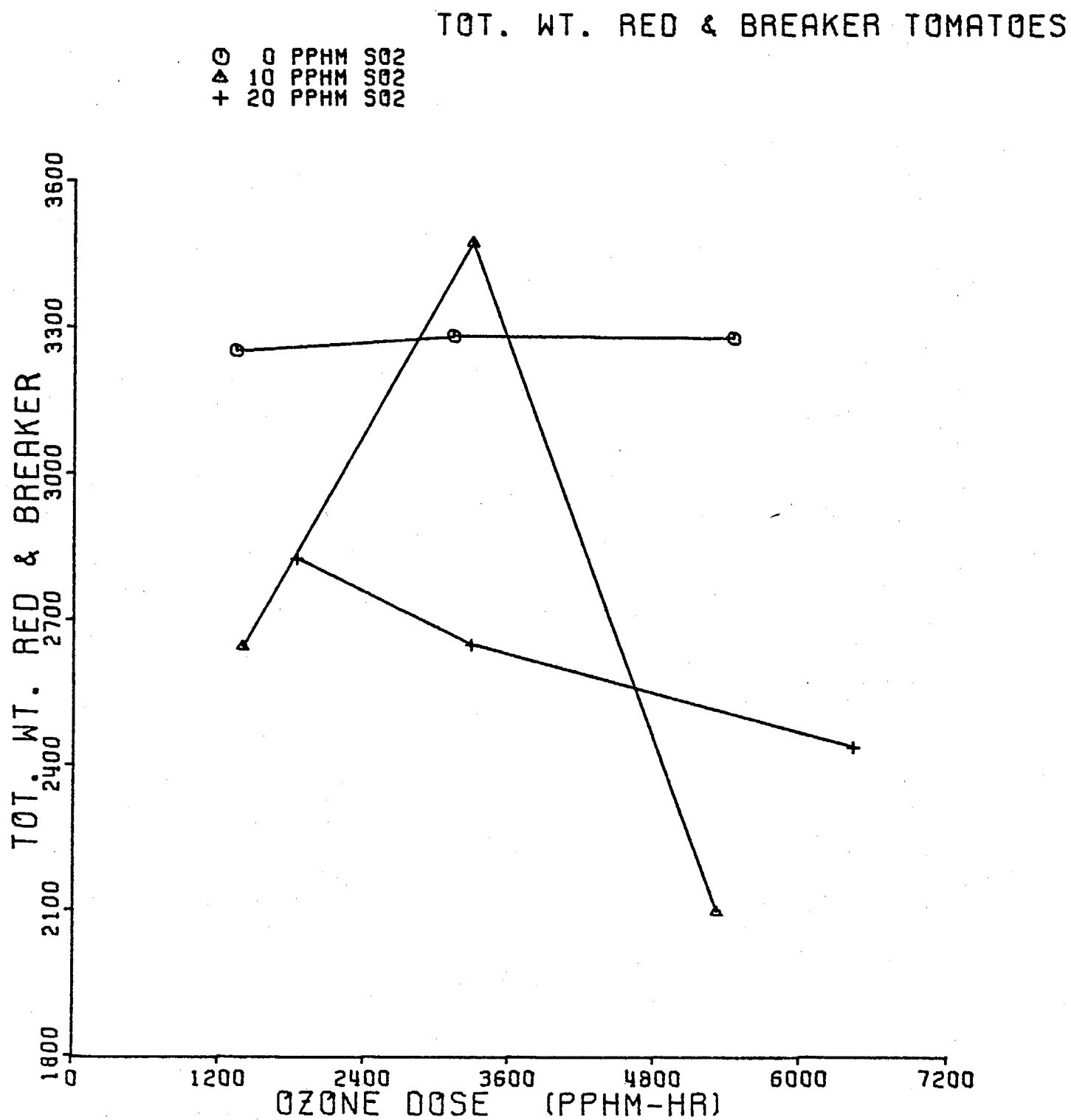


Table 6. Analysis of Variance of Variable 2 - No. Red & Breaker Tomatoes

Source of Variation	df	SS	MS	F	Coefficient of variation
B	1	1.394450	1.394450	0.02	
O	2	112.863700	56.431870	0.79	
Linear	1	71.343440	71.343440	1.00	
Quadratic	1	41.520350	41.520350	0.58	
S	2	608.720800	304.360400	4.26	
Linear	1	470.501400	470.501400	6.58*	
Quadratic	1	138.219100	138.219100	1.93	
S x O	4	486.942500	121.735600	1.70	
SL OL	1	6.816047	6.816047	0.10	
SQ OL	1	141.264700	141.264700	1.98	
SL OQ	1	1.484647	1.484647	0.02	
SQ OQ	1	337.377000	337.377000	4.72	
Error	8	571.815400	71.476910		15.0%
TOTAL	17	1781.737000			

Combination	Count per Mean	Subclass			Means
		B	S	O	
B	9				
		1	0	0	56.70
		2	0	0	56.14
O	6				
1530 pphm-hr		0	0	1	57.43
3243 pphm-hr		0	0	2	58.86
5740 pphm-hr		0	0	3	52.98
S	6				
0 pphm		0	1	0	64.64
10 pphm		0	2	0	52.50
20 pphm		0	3	0	52.12
S x O	2				
		0	1	1	64.78
		0	2	1	52.93
		0	3	1	54.57
		0	1	2	62.86
		0	2	2	64.14
		0	3	2	49.57
		0	1	3	66.28
		0	2	3	40.43
		0	3	3	52.21

* = significance at .05

Figure 7. Effect of Ozone and SO₂ on the Total Number of Red & Breaker Tomatoes

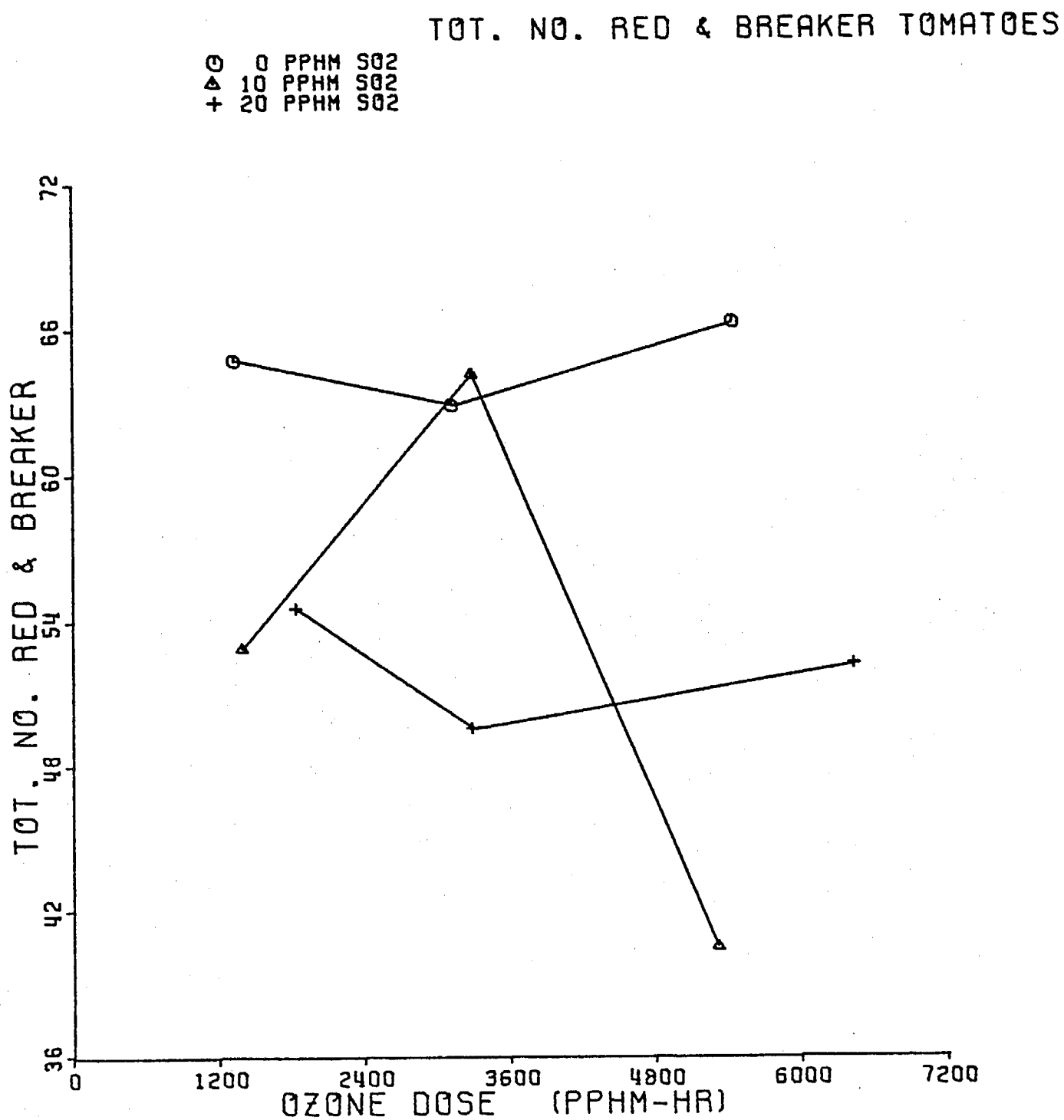


Table 7. Analysis of Variance of Variable 3 - Total No. Red Tomatoes

Source of Variation	df	SS	MS	F	Coefficient of variation
B	1	0.19427	0.19427	0.00	
O	2	172.56330	86.28166	1.40	
Linear	1	138.01210	138.01210	2.24	
Quadratic	1	34.55133	34.55133	0.56	
S	2	703.92290	351.96140	5.70*	
Linear	1	518.37290	518.37290	8.39*	
Quadratic	1	185.54970	185.54970	3.00	
S x O	4	382.10340	95.52583	1.55	
SL OL	1	3.14152	3.14152	0.05	
SQ OL	1	54.10844	54.10844	0.88	
SL OQ	1	0.95766	0.95766	0.02	
SQ OQ	1	323.89560	323.89560	5.25	
Error	8	493.98660	61.74832		15.7%
TOTAL	17	1752.77000			

Combination	Count per Mean	Subclass			Means
		B	S	O	
B	9				
		1	0	0	49.84
		2	0	0	50.05
O	6				
1530 pphm-hr		0	0	1	51.95
3243 pphm-hr		0	0	2	52.31
5740 pphm-hr		0	0	3	45.57
S	6				
0 pphm		0	1	0	58.79
10 pphm		0	2	0	45.40
20 pphm		0	3	0	45.64
S x O	2				
		0	1	1	61.07
		0	2	1	45.21
		0	3	1	49.57
		0	1	2	57.07
		0	2	2	56.57
		0	3	2	43.28
		0	1	3	58.21
		0	2	3	34.42
		0	3	3	44.07

* = significance at .05

Table 8. Analysis of Variance of Variable 4 - Total Wt. Red Tomatoes

Source of Variation	df	SS	MS	F	Coefficient of variation
B	1	144313.400	144313.400	1.04	
O	2	908524.000	454261.900	3.26	
Linear	1	546716.400	546716.400	3.92	
Quadratic	1	361807.900	361807.900	2.60	
S	2	1616063.000	808031.600	5.80*	
Linear	1	1246340.000	1246340.000	8.94*	
Quadratic	1	369722.400	369722.400	2.65	
S x O	4	966576.600	241644.100	1.73	
SL OL	1	47988.700	47988.700	0.34	
SQ OL	1	18749.580	18749.580	0.13	
SL OQ	1	3116.907	3116.907	0.02	
SQ OQ	1	896721.300	896721.300	6.43	
Error	8	1115027.000	139378.400		14.6%
TOTAL	17	4750505.000			

Combination	Count per Mean	Subclass			Means
		B	S	O	
B	9				
		1	0	0	2463.31
		2	0	0	2642.39
O	6				
1530 pphm-hr		0	0	1	2633.71
3243 pphm-hr		0	0	2	2778.51
5740 pphm-hr		0	0	3	2246.32
S	6				
0 pphm		0	1	0	2976.46
10 pphm		0	2	0	2350.16
20 pphm		0	3	0	2331.91
S x O	2				
		0	1	1	3077.18
		0	2	1	2219.98
		0	3	1	2603.97
		0	1	2	2989.87
		0	2	2	3026.56
		0	3	2	2319.09
		0	1	3	2862.34
		0	2	3	1803.95
		0	3	3	2072.67

* = significance at .05

Figure 8. Effect of Ozone and SO₂ on the Total Number of Red Tomatoes

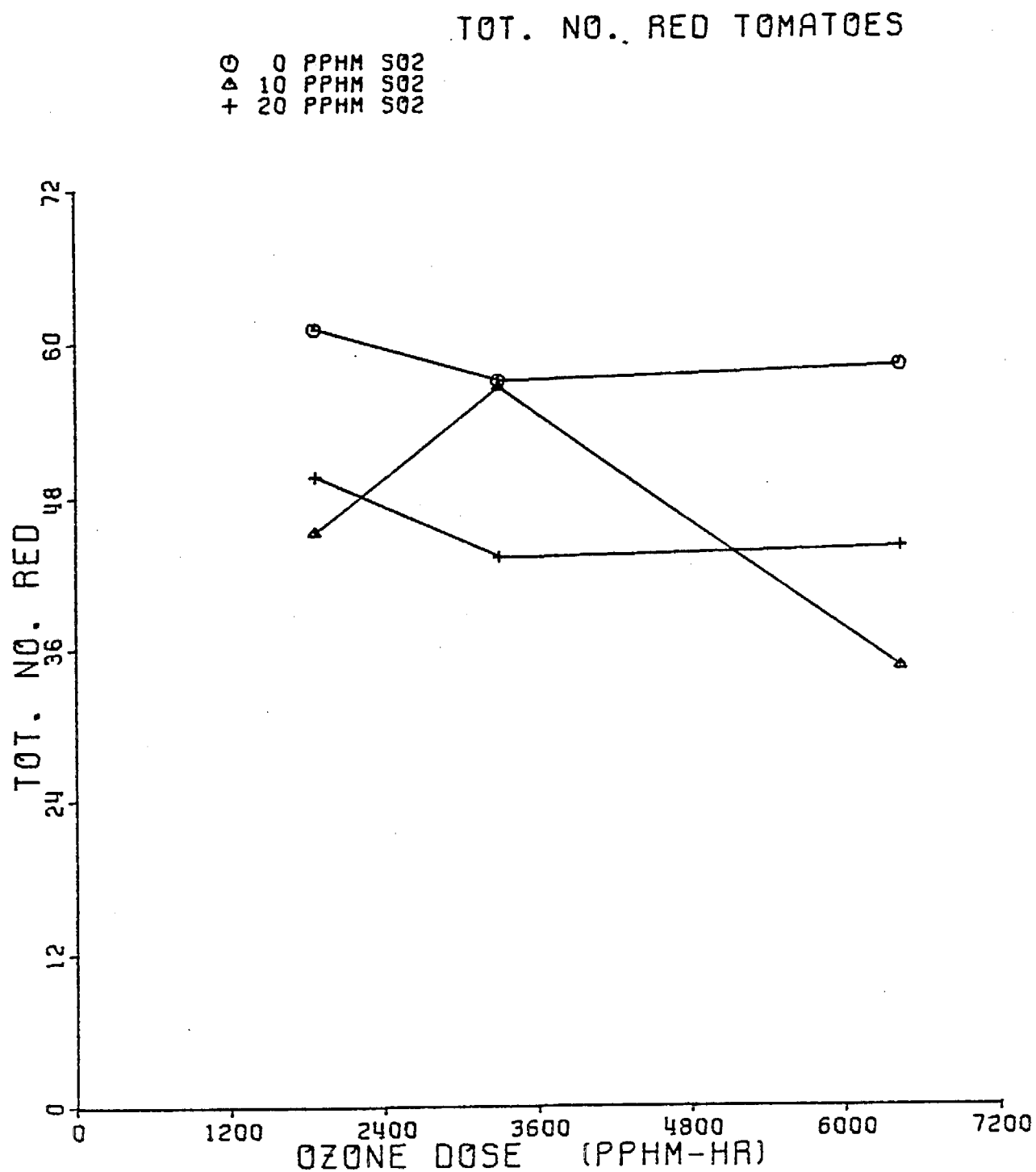


Figure 9. Effect of Ozone and SO₂ on the Total Weight of Red Tomatoes

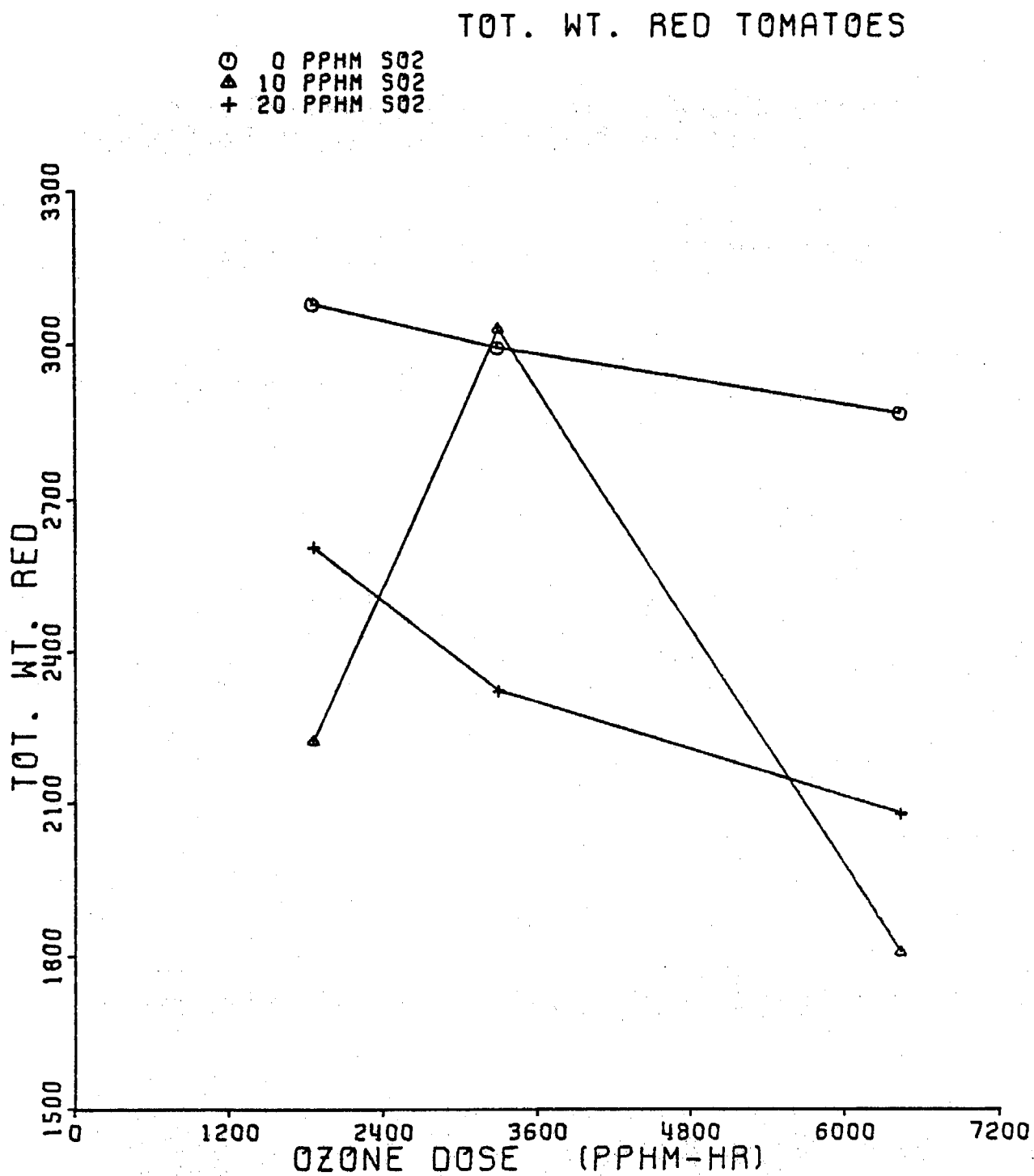


Table 9. Analysis of Variance of Variable 5 - Total No. Breaker Tomatoes

Source of Variation	df	SS	MS	F	Coefficient of variation
B	1	2.39805	2.39805	1.97	
O	2	10.96830	5.48415	4.51*	
Linear	1	10.56438	10.56438	8.69*	
Quadratic	1	0.40391	0.40391	0.33	
S	2	4.61280	2.30640	1.90	
Linear	1	1.15320	1.15320	0.95	
Quadratic	1	3.45960	3.45960	2.85	
S x O	4	21.02180	5.25544	4.32*	
SL OL	1	0.61417	0.61417	0.51	
SQ OL	1	20.19861	20.19861	16.62**	
SL OQ	1	0.10122	0.10122	0.08	
SQ OQ	1	0.10777	0.10777	0.09	
Error	8	9.72530	1.21566		17.0%
TOTAL	17	48.72625			

Combination	Count per Mean	Subclass			Means
		B	S	O	
B	9				
		1	0	0	6.84
		2	0	0	6.11
O	6				
1530 pphm-hr		0	0	1	5.47
3243 pphm-hr		0	0	2	6.57
5740 pphm-hr		0	0	3	7.38
S	6				
0 pphm		0	1	0	5.85
10 pphm		0	2	0	7.09
20 pphm		0	3	0	6.47
S x O	2				
		0	1	1	3.71
		0	2	1	7.71
		0	3	1	5.00
		0	1	2	5.85
		0	2	2	7.57
		0	3	2	6.28
		0	1	3	8.00
		0	2	3	6.00
		0	3	3	8.14

* = significance at .05

** = significance at .01

Table 10. Analysis of Variance of Variable 6 - Total Wt. Breaker Tomatoes

Source of Variation	df	SS	MS	F	Coefficient of variation
B	1	839.9534	839.9534	0.34	
O	2	27282.6900	13641.3400	5.54*	
Linear	1	17492.9000	17492.9000	7.10*	
Quadratic	1	9789.7930	9789.7930	3.97	
S	2	32457.7200	16228.8600	6.59*	
Linear	1	355.2322	355.2322	0.14	
Quadratic	1	32102.5000	32102.5000	13.03**	
S x O	4	78779.2900	19694.8200	7.99**	
SL OL	1	4750.7480	4750.7480	1.93	
SQ OL	1	71898.4700	71898.4700	29.18***	
SL OQ	1	560.5964	560.5964	0.23	
SQ OQ	1	1569.3900	1569.3900	0.64	
Error	8	19710.2000	2463.7750		15.1%
TOTAL	17	159069.9000			

Combination	Count per Mean	Subclass			Means
		B	S	O	
B	9	1	0	0	335.07
		2	0	0	321.40
O	6	0	0	1	273.18
1530 pphm-hr		0	0	2	356.32
3243 pphm-hr		0	0	3	355.20
S	6	0	1	0	292.93
0 pphm		0	2	0	387.96
10 pphm		0	3	0	303.81
20 pphm		0	1	1	175.30
S x O	2	0	2	1	423.99
		0	3	1	220.24
		0	1	2	292.37
		0	2	2	448.10
		0	3	2	328.48
		0	1	3	411.11
		0	2	3	291.78
		0	3	3	362.71

* = significance at .05

** = significance at .01

*** = significance at .001

Figure 10. Effect of Ozone and SO₂ on the Total Number of Breaker Tomatoes

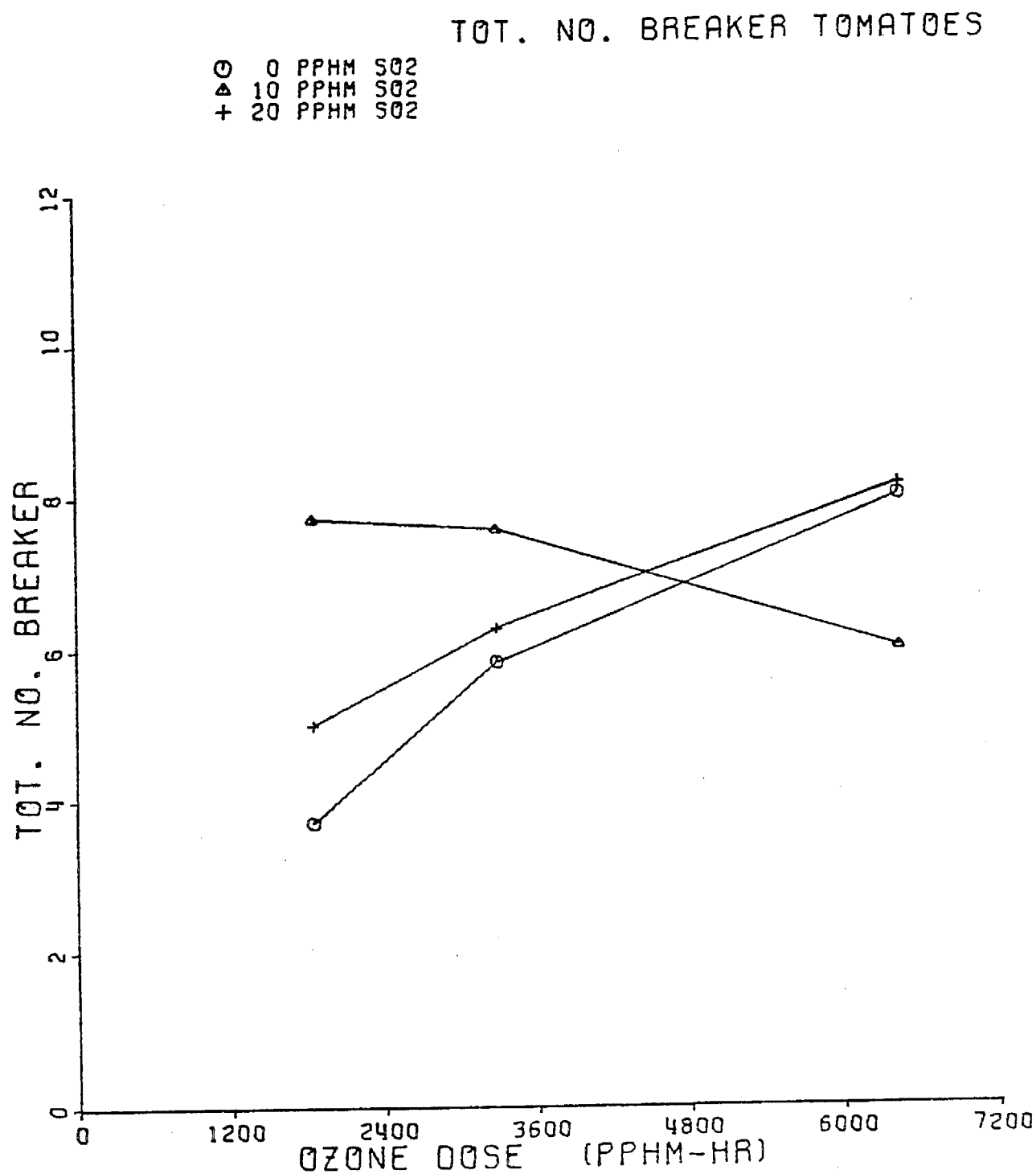


Figure 11. Effect of Ozone and SO₂ on the Total Weight of Breaker Tomatoes (grams)

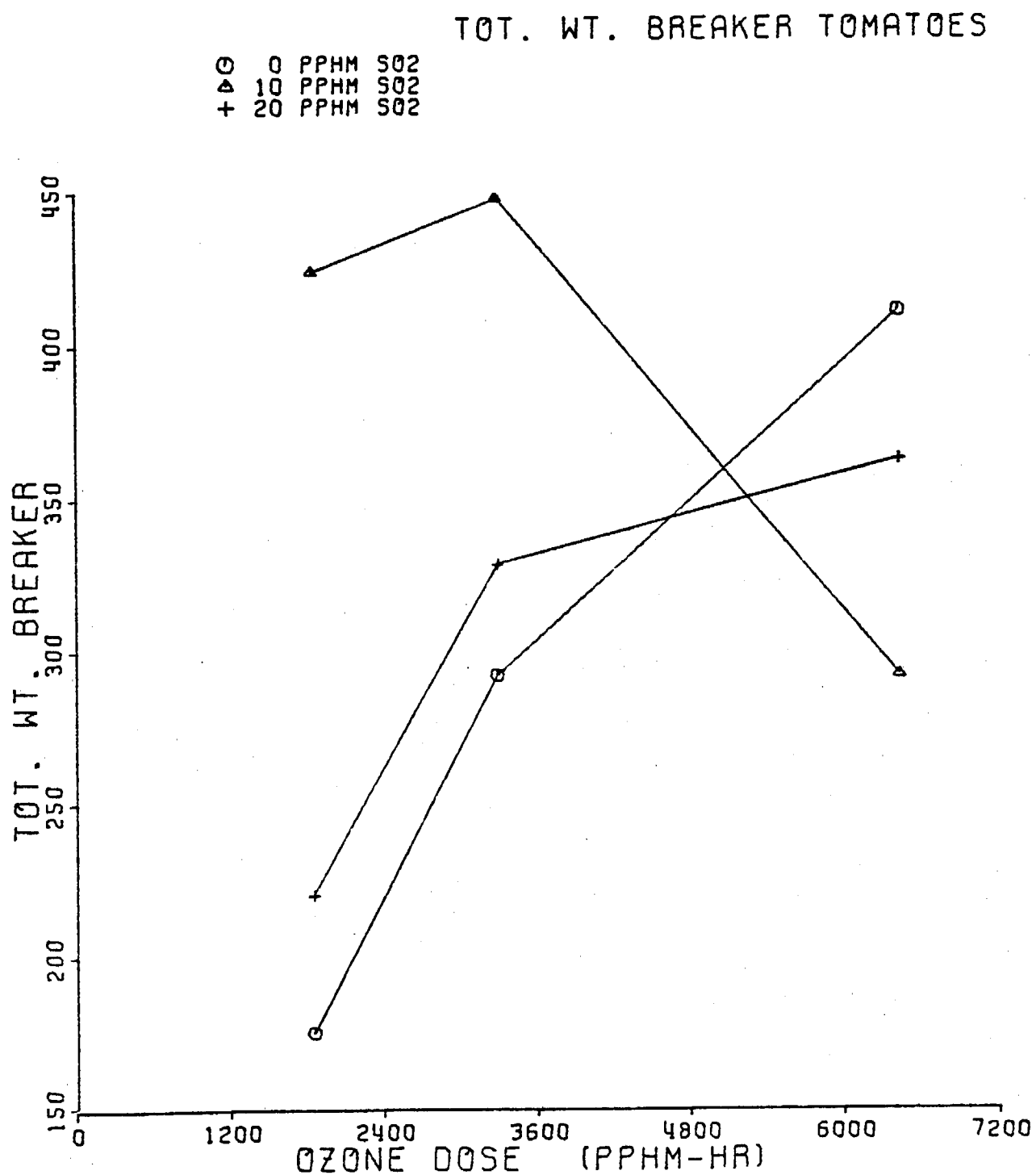


Table 11. Analysis of Variance of Variable 7 - Pulp Color

Source of Variation	df	SS	MS	F	Coefficient of variation
B	1	0.286272	0.286272	0.09	
O	2	5.852578	2.926289	0.96	
Linear	1	0.391826	0.391826	0.13	
Quadratic	1	5.460751	5.460751	1.79	
S	2	26.175240	13.087620	4.30	
Linear	1	26.166550	26.166550	8.60*	
Quadratic	1	0.008711	0.008711	0.00	
S x O	4	11.323360	2.830839	0.93	
SL OL	1	0.501018	0.501018	0.16	
SQ OL	1	2.325612	2.325612	0.76	
SL OQ	1	3.811851	3.811851	1.25	
SQ OQ	1	4.684881	4.684881	1.54	
Error	8	24.347980	3.043497		5.9%
TOTAL	17	67.985430			

Combination	Count per Mean	Subclass			Means
		B	S	O	
B	9				
		1	0	0	29.32
		2	0	0	29.57
O	6				
1530 pphm-hr		0	0	1	30.07
3243 pphm-hr		0	0	2	28.69
5740 pphm-hr		0	0	3	29.57
S	6				
0 pphm		0	1	0	27.95
10 pphm		0	2	0	29.47
20 pphm		0	3	0	30.90
S x O	2				
		0	1	1	27.28
		0	2	1	31.28
		0	3	1	31.64
		0	1	2	28.43
		0	2	2	27.78
		0	3	2	29.86
		0	1	3	28.14
		0	2	3	29.35
		0	3	3	31.21

* = significance at .05

Figure 12. Effect of Ozone and SO₂ on the Pulp Color of Tomato.
(Low Agtron No. = High Color Intensity)

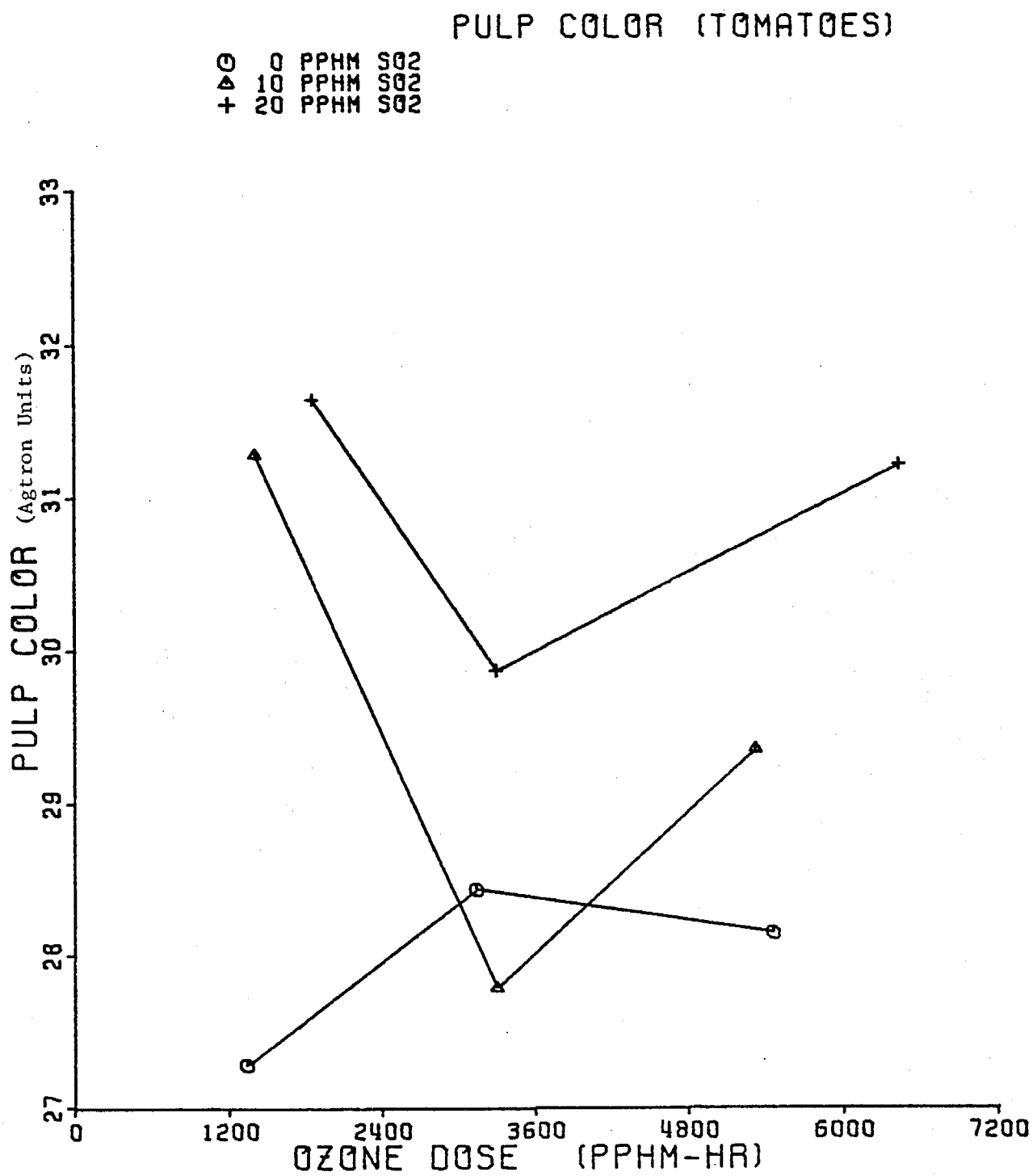


Table 12. Analysis of Variance of Variable 8 - pH.

Source of Variation	df	SS	MS	F	Coefficient of variation
B	1	0.0098000	0.0097999	10.59*	
O	2	0.0016777	0.0008388	0.91	
Linear	1	0.0001052	0.0001052	0.11	
Quadratic	1	0.0015725	0.0015725	1.70	
S	2	0.0024111	0.0012055	1.30	
Linear	1	0.0021333	0.0021333	2.31	
Quadratic	1	0.0002777	0.0002777	0.30	
S x O	4	0.0206222	0.0051555	5.57*	
SL OL	1	0.0057609	0.0057609	6.23*	
SQ OL	1	0.0001982	0.0001982	0.21	
SL OQ	1	0.0146557	0.0146557	15.84**	
SQ OQ	1	0.0000072	0.0000072	0.01	
Error	8	0.0074000	0.0009249		0.7%
TOTAL	17	0.0419111			

Combination	Count per Mean	Subclass			Means
		B	S	O	
B	9				
		1	0	0	4.18
		2	0	0	4.23
O	6				
1530 pphm-hr		0	0	1	4.19
3243 pphm-hr		0	0	2	4.21
5740 pphm-hr		0	0	3	4.20
S	6				
0 pphm		0	1	0	4.22
10 pphm		0	2	0	4.20
20 pphm		0	3	0	4.19
S x O	2				
		0	1	1	4.26
		0	2	1	4.18
		0	3	1	4.13
		0	1	2	4.18
		0	2	2	4.21
		0	3	2	4.25
		0	1	3	4.20
		0	2	3	4.20
		0	3	3	4.19

* = significance at .05

** = significance at .01

Table 13. Analysis of Variance of Variable 9 - Plant Dry Wt.

Source of Variation	df	SS	MS	F	Coefficient of variation
B	1	4579.24500	4579.24400	15.29**	
O	2	169.30330	84.65166	0.28	
Linear	1	5.91086	5.91086	0.02	
Quadratic	1	163.39250	163.39250	0.55	
S	2	1445.94300	722.97160	2.41	
Linear	1	88.02087	88.02087	0.29	
Quadratic	1	1357.92200	1357.92200	4.53	
S x O	4	1944.88300	486.22080	1.62	
SL OL	1	570.68240	570.68240	1.90	
SQ OL	1	645.20870	645.20870	2.15	
SL OQ	1	716.76990	716.76990	2.39	
SQ OQ	1	12.22238	12.22238	0.04	
Error	8	2396.67000	299.58370		9.1%
TOTAL	17	10536.04000			

Combination	Count per Mean	Subclass			Means
		B	S	O	
B	9	1	0	0	173.77
		2	0	0	205.67
O	6	0	0	1	192.88
1530 pphm-hr		0	0	2	185.57
3243 pphm-hr		0	0	3	190.70
5740 pphm-hr					
S	6	0	1	0	193.15
0 pphm		0	2	0	177.43
10 pphm		0	3	0	198.57
20 pphm					
S x O	2	0	1	1	193.40
		0	2	1	189.30
		0	3	1	195.95
		0	1	2	199.45
		0	2	2	176.20
		0	3	2	181.05
		0	1	3	186.60
		0	2	3	166.80
		0	3	3	218.70

** = significance at .01

Table 14. Mean Data for Each Treatment Plot of the Response Factors Measured in the Regression Analysis Experiment for VF145B-7879 Tomato Exposed to Various Concentrations of SO₂ and Polluted Ambient Air (Page 1 of 2)

Chamber #	Block	Level SO ₂ ppm	Filtered ambient air (%)	Total no. red tomatoes	Total wt. red tomatoes (g)	Total no. breaker tomatoes	Total wt. breaker tomatoes (g)	Total no. green tomatoes	Total wt. green tomatoes (g)	Total no. red + breaker tomatoes	Total wt. red + breaker tomatoes (g)
7	1	0	100	60.29	2983.36	3.71	180.04	11.57	413.97	64.00	3163.40
3	1	10	100	52.71	2425.49	8.29	394.89	10.86	331.56	61.00	2820.37
10	1	20	100	41.57	2079.69	5.43	219.36	22.71	729.56	47.00	2299.04
2	1	0	75	51.14	2660.59	5.00	255.61	9.57	331.23	56.14	2916.17
6	1	10	75	57.86	2957.14	8.14	467.87	8.14	343.51	66.00	3425.01
1	1	20	75	49.00	2568.39	6.57	348.87	11.14	362.30	55.57	2917.26
5	1	0	50	56.57	2785.99	7.71	386.23	13.14	539.93	64.43	3179.63
4	1	10	50	29.71	1487.31	6.57	326.26	43.86	1604.26	36.29	1813.57
8	1	20	50	49.71	2221.84	10.14	436.46	18.29	634.24	59.86	2658.30
9	1	0	25	61.29	2736.24	10.71	505.43	10.29	332.26	72.0	3241.67
17	2	0	100	61.86	3171.00	3.71	170.57	15.86	642.73	65.57	3341.57
13	2	10	100	37.71	2014.47	7.14	453.09	38.29	1551.41	44.86	2467.56
20	2	20	100	57.57	3128.26	4.57	221.13	26.00	1174.73	62.14	3349.39
12	2	0	75	63.00	3319.19	6.71	329.14	22.00	758.01	69.57	3648.33
16	2	10	75	55.29	3095.99	7.00	428.34	16.00	556.06	62.29	3524.33
11	2	20	75	37.57	2069.79	6.00	308.10	39.14	1569.74	43.57	2377.89
15	2	0	50	59.86	2938.69	8.29	436.00	25.57	1043.54	68.14	3374.69
14	2	10	50	39.14	2120.59	5.43	257.30	21.00	661.77	44.57	2377.89
18	2	20	50	38.43	1923.51	6.14	288.96	31.29	1297.60	44.57	2212.47
19	2	0	25	66.57	3275.8	6.71	304.23	13.0	449.47	73.29	3580.03
AMB1	---	---	---	8.43	348.5	8.71	320.23	46.57	1201.03	17.14	668.7
AMB2	---	---	---	28.14	967.6	16.0	553.6	30.86	627.93	44.14	1521.2

Table 14 continued (Page 2 of 2)

Chamber #	Pulp color	Soluble solids	pH	Plant dry wt. (g)	% No. red tomatoes	% No. breaker tomatoes	% No. green tomatoes	% No. red + breaker tomatoes	% Wt. red tomatoes	% Wt. breaker tomatoes	% Wt. green tomatoes	% Wt. red + breaker tomatoes
7	26.86	5.97	4.24	182.1	79.78	4.91	15.31	84.69	83.40	5.03	11.57	88.43
3	30.00	5.77	4.17	173.9	73.35	11.54	15.11	84.89	76.95	12.53	10.52	89.48
10	32.29	6.30	4.07	169.0	59.63	7.79	32.58	67.42	68.67	7.24	24.09	75.91
2	27.43	6.06	4.14	168.4	77.83	7.61	14.56	85.44	81.93	7.87	10.20	89.80
6	27.71	5.79	4.21	170.2	78.04	10.98	10.98	89.02	78.47	12.42	9.12	90.88
1	28.86	5.78	4.24	171.8	73.45	9.85	16.70	83.30	78.32	10.64	11.05	88.95
5	27.71	5.54	4.21	181.0	73.07	9.96	16.97	83.22	75.05	10.40	14.54	85.65
4	32.14	5.19	4.17	164.5	37.07	8.20	54.73	45.28	43.52	9.55	46.94	53.06
8	30.86	5.73	4.16	183.0	63.62	12.98	23.41	76.61	67.48	13.26	19.26	80.74
9	27.14	5.64	4.20	177.8	74.48	13.02	12.5	87.5	76.56	14.14	9.30	90.70
17	27.71	6.00	4.29	204.7	75.97	4.56	19.48	80.52	79.59	4.28	16.13	83.87
13	32.57	5.40	4.19	204.7	45.36	8.59	46.05	53.96	50.12	11.27	38.60	61.40
20	31.00	5.67	4.19	222.9	65.32	5.18	29.50	70.50	69.15	4.89	25.97	74.03
12	29.43	5.51	4.23	230.5	68.69	7.32	23.99	75.86	75.33	7.47	17.20	82.80
16	27.86	5.73	4.21	182.2	70.62	8.94	20.44	79.56	75.87	10.50	13.63	86.37
11	30.86	5.29	4.26	190.3	45.42	7.25	47.32	52.68	52.43	7.80	39.76	60.24
15	28.57	5.40	4.20	192.2	63.87	8.85	27.28	72.71	66.51	9.87	23.62	76.38
14	26.57	5.90	4.23	169.1	59.69	8.28	32.03	67.97	69.76	8.46	21.77	78.23
18	31.56	5.50	4.23	254.4	50.66	8.09	41.25	58.75	54.80	8.23	36.97	63.03
19	27.71	5.31	4.17	192.9	77.15	7.78	15.07	84.93	81.30	7.55	11.15	88.85
AMB1	43.57	5.29	4.30	165.3	13.23	13.68	73.09	26.91	18.64	17.13	64.23	35.77
AMB2	38.86	5.31	4.23	153.5	37.52	21.33	41.14	58.86	45.02	25.76	29.22	70.78

Table 15. Doses of SO₂ and Calculated Doses of Ozone Used in the Experiment Designed for Regression Analysis

Chamber #	Block	Level SO ₂ pphm	Filtered ambient air (%)	Dose >0 pphm/hrs	Dose >3 pphm/hrs	Dose >5 pphm/hrs	Dose >8 pphm/hrs	Dose >10 pphm/hrs	Dose >15 pphm/hrs	Dose >20 pphm/hrs
7	1	0	100	1456	1	0	0	0	0	0
3	1	10	100	1479	2	0	0	0	0	0
10	1	20	100	2016	3	0	0	0	0	0
2	1	0	75	2938	349	30	0	0	0	0
6	1	10	75	3132	326	18	0	0	0	0
1	1	20	75	3635	619	95	0	0	0	0
5	1	0	50	5296	1700	576	54	6	0	0
4	1	10	50	5273	1872	701	85	9	0	0
8	1	20	50	6638	2435	1041	167	30	0	0
9	1	0	25	8445	3969	2283	694	228	3	0
17	2	0	100	1220	0	0	0	0	0	0
13	2	10	100	1328	0	0	0	0	0	0
20	2	20	100	1681	2	0	0	0	0	0
12	2	0	75	3334	615	100	0	0	0	0
16	2	10	75	3466	548	58	0	0	0	0
11	2	20	75	2956	365	31	0	0	0	0
15	2	0	50	5628	1929	724	83	7	0	0
14	2	10	50	5366	1959	783	103	13	0	0
18	2	20	50	6237	2178	869	109	12	0	0
19	2	0	25	8091	3611	1942	547	168	2	0
AMB1	--	--	--	11671	7827	5914	3677	2537	824	180
AMB2	---	---	---	11671	7827	5914	3677	2537	824	180

Figure 13. Total Weight (Grams) of Red and Breaker Tomato Fruit
Produced by VF145B-7879 Tomato Plants Treated with
Five Dose Levels of Ozone

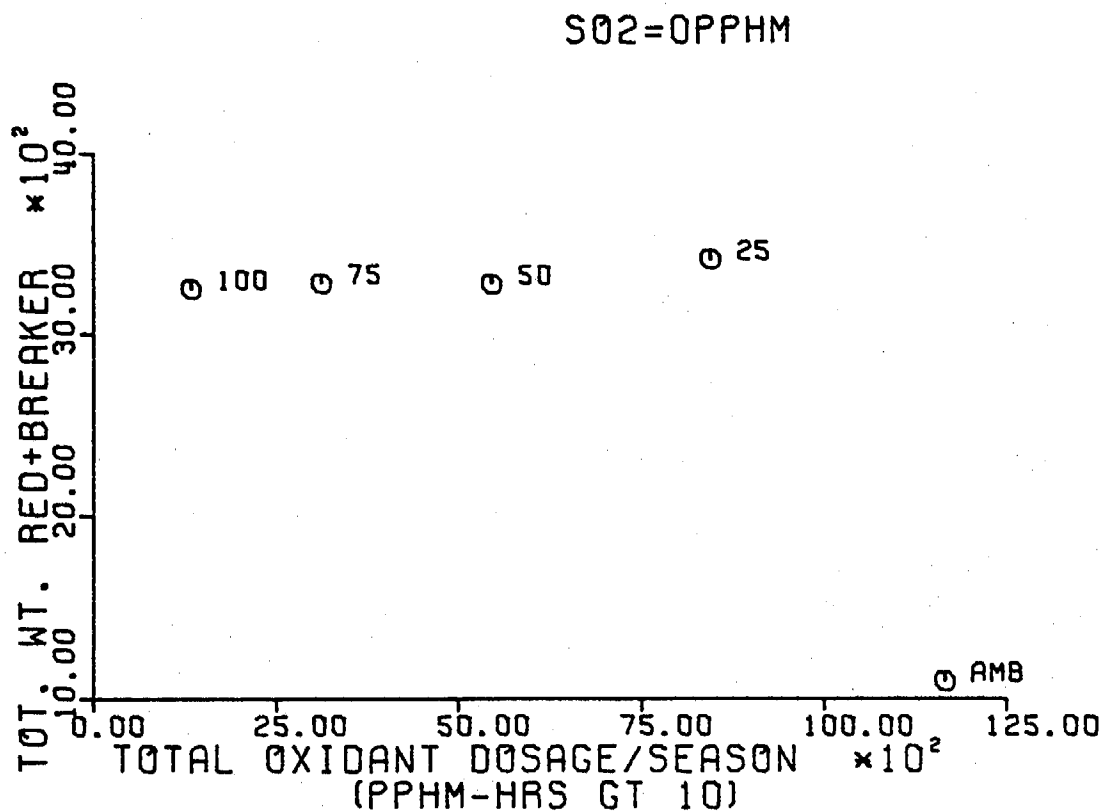


Figure 14. Fruit Size Distribution for Treatment Replicates by
Number and Percent of Fruit in 25-gram Weight Categories (Page 1 of 4)

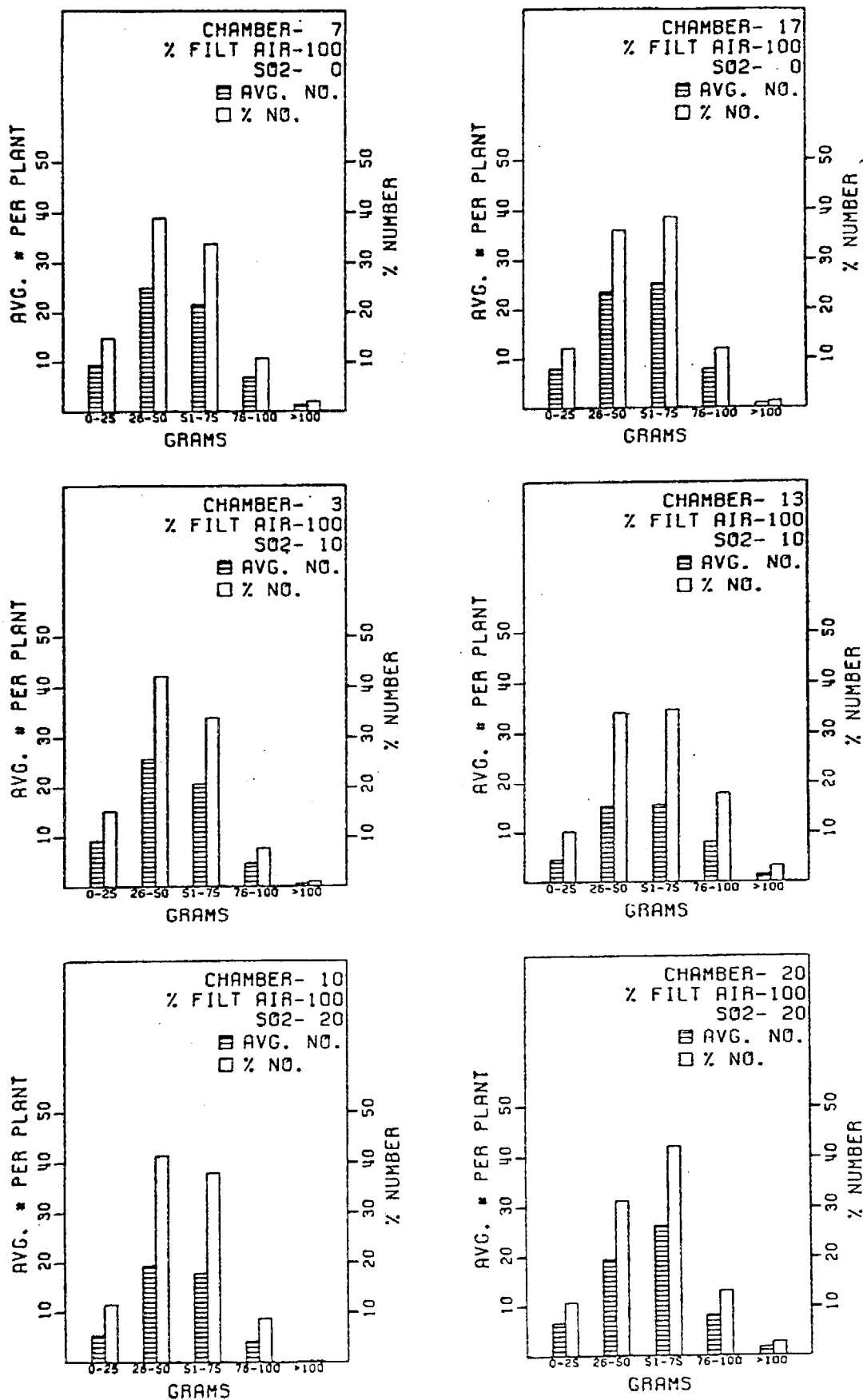


Figure 14 continued (Page 2 of 4)

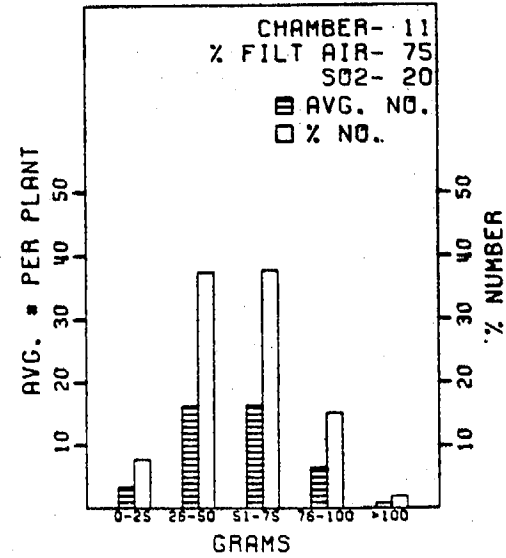
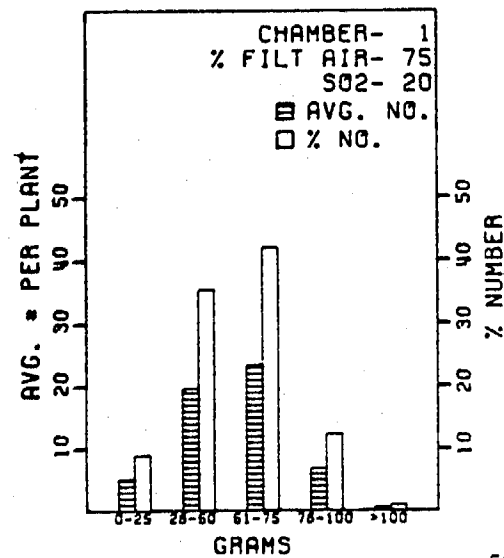
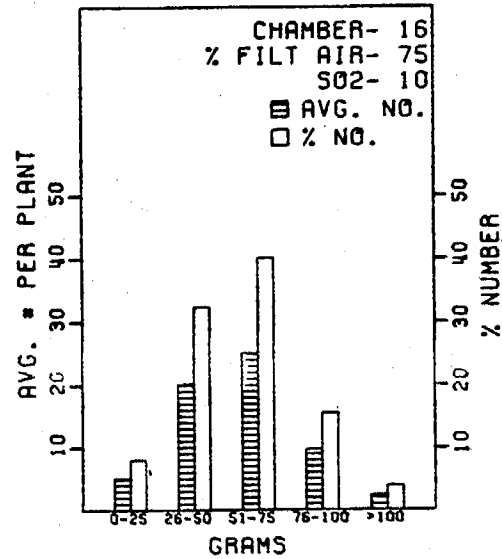
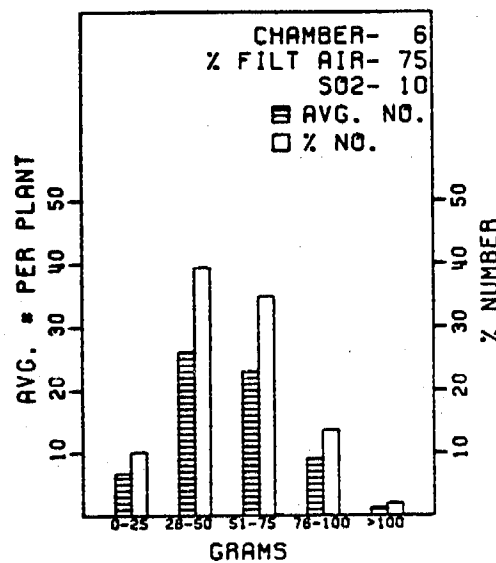
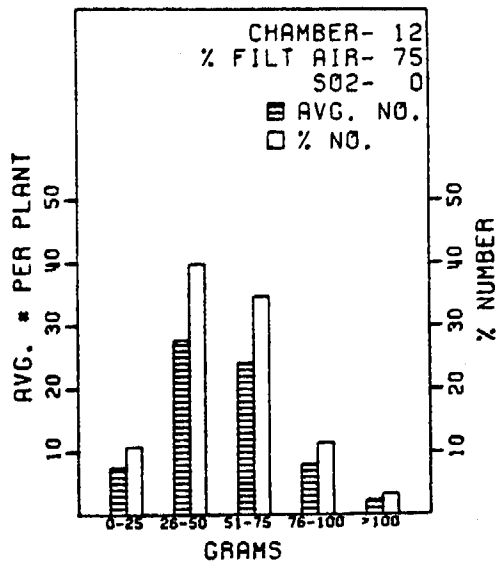
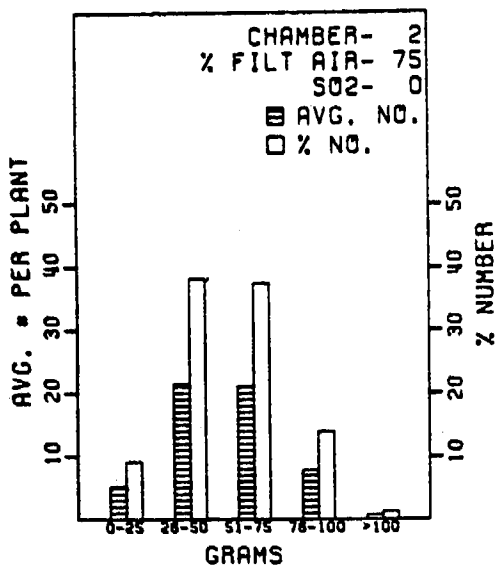


Figure 14 continued (Page 3 of 4)

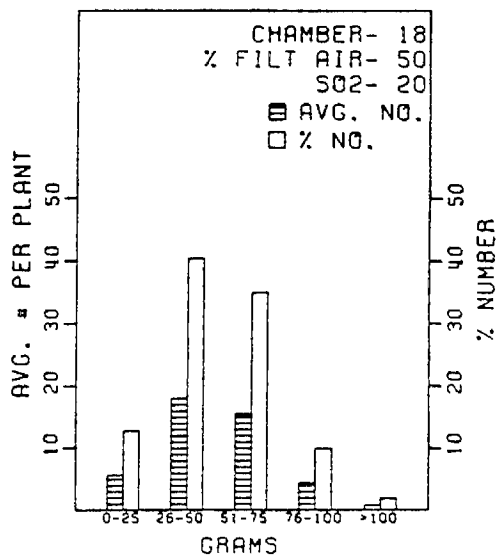
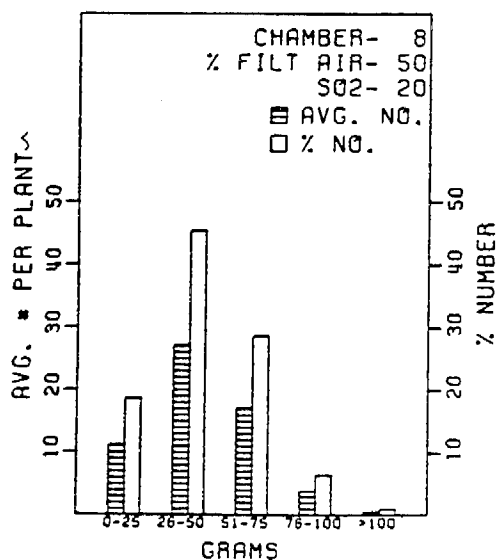
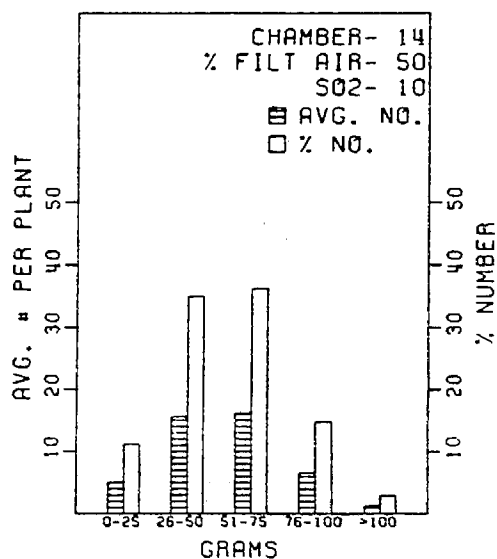
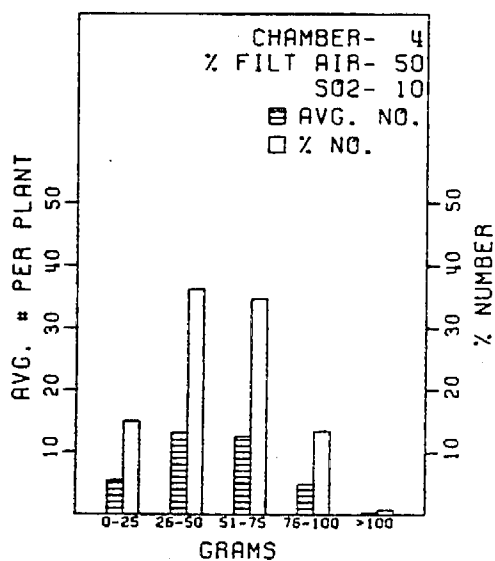
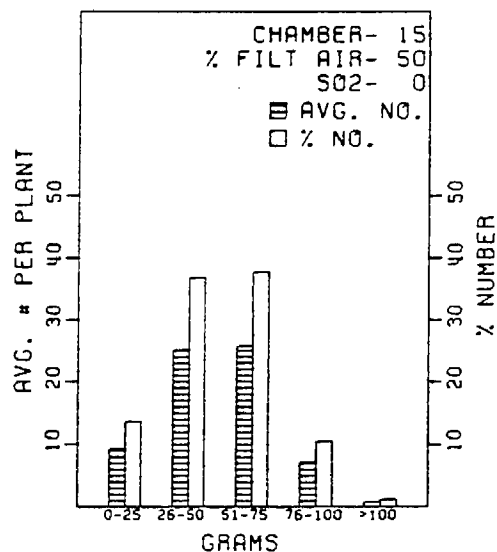
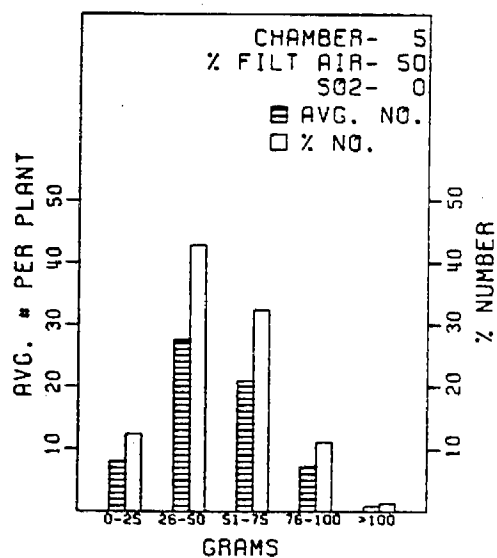


Figure 14 continued (Page 4 of 4)

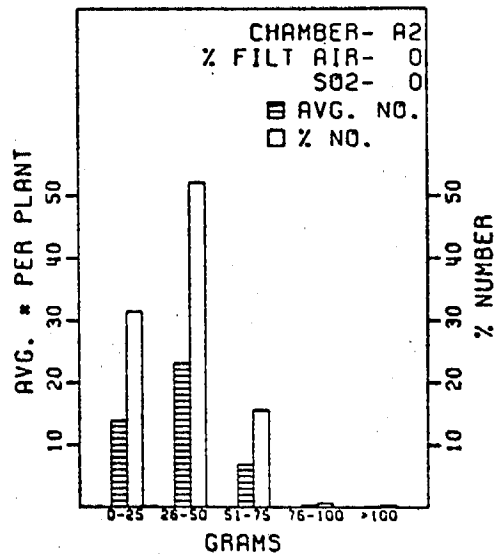
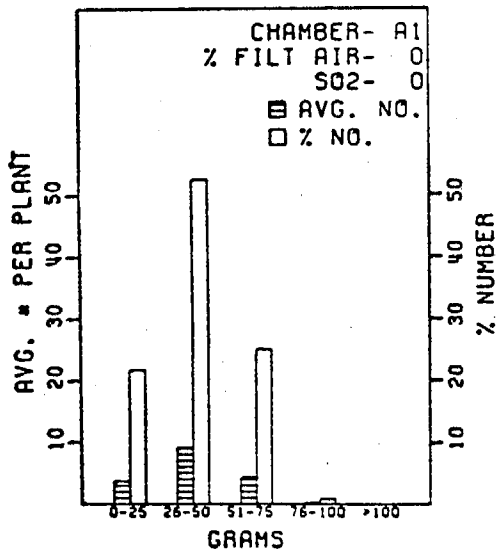
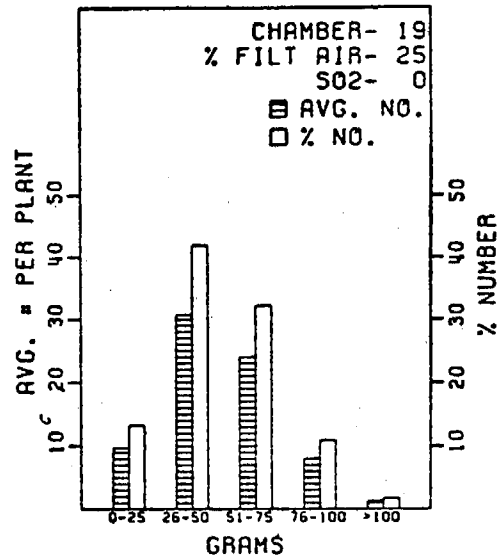
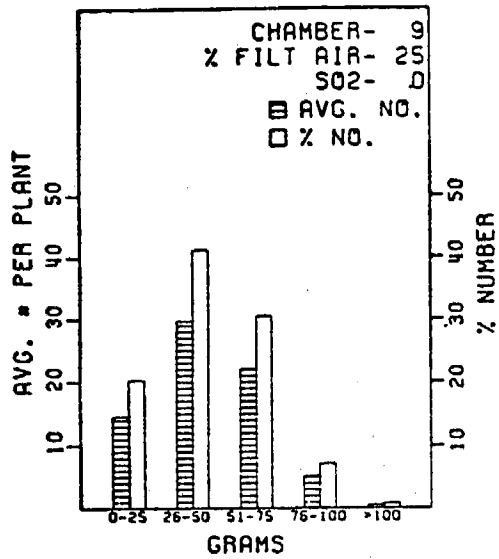


Figure 15. Relationship of Ozone Treatments by Chamber Number to the Commercial Yield of VF 145B-7879 Processing Tomato

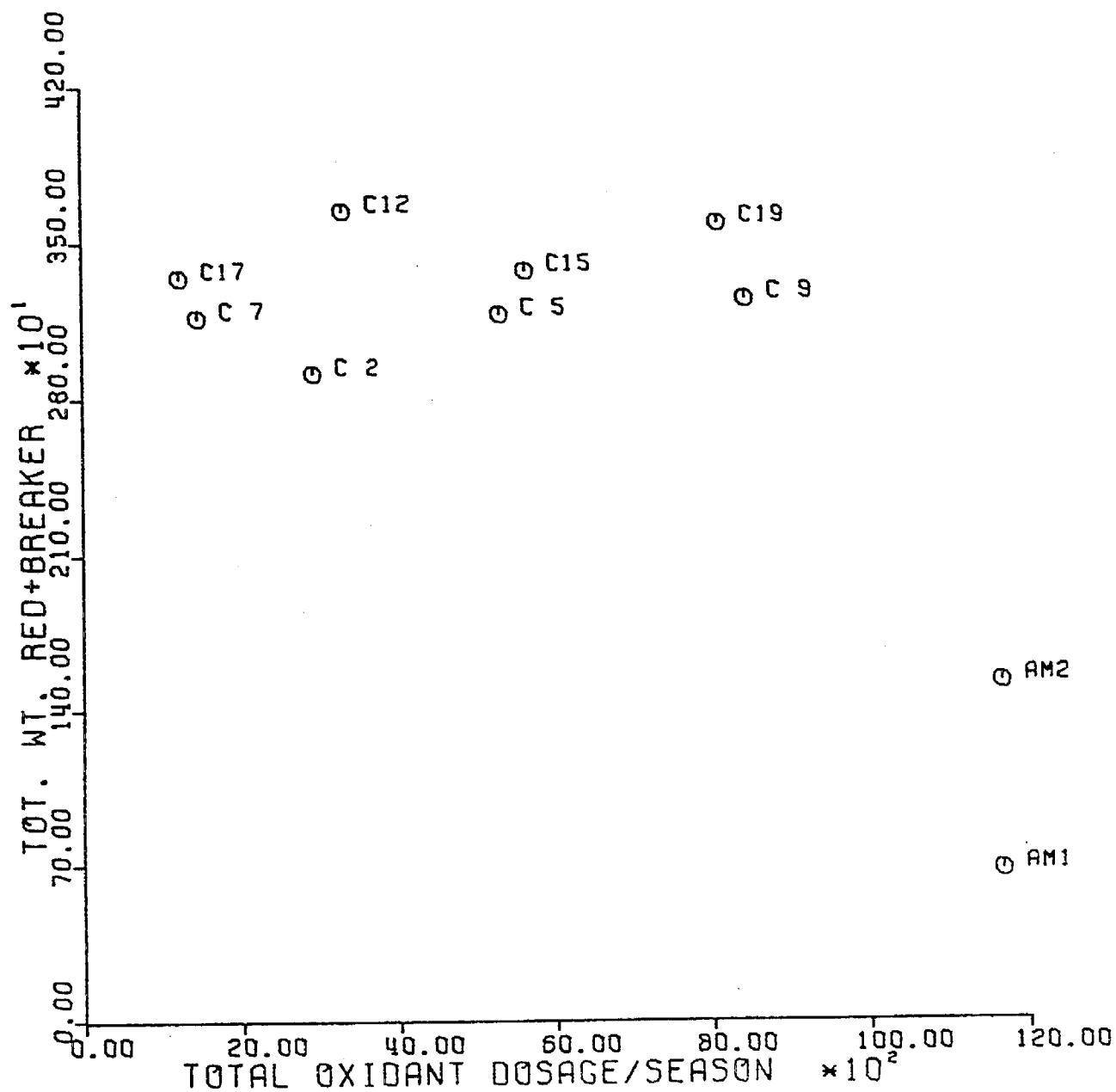


Figure 16. Comparison of Photosynthetically Active Radiation (PAR) Curve for Chamber 2 with the Ambient Curve June 19, 1978

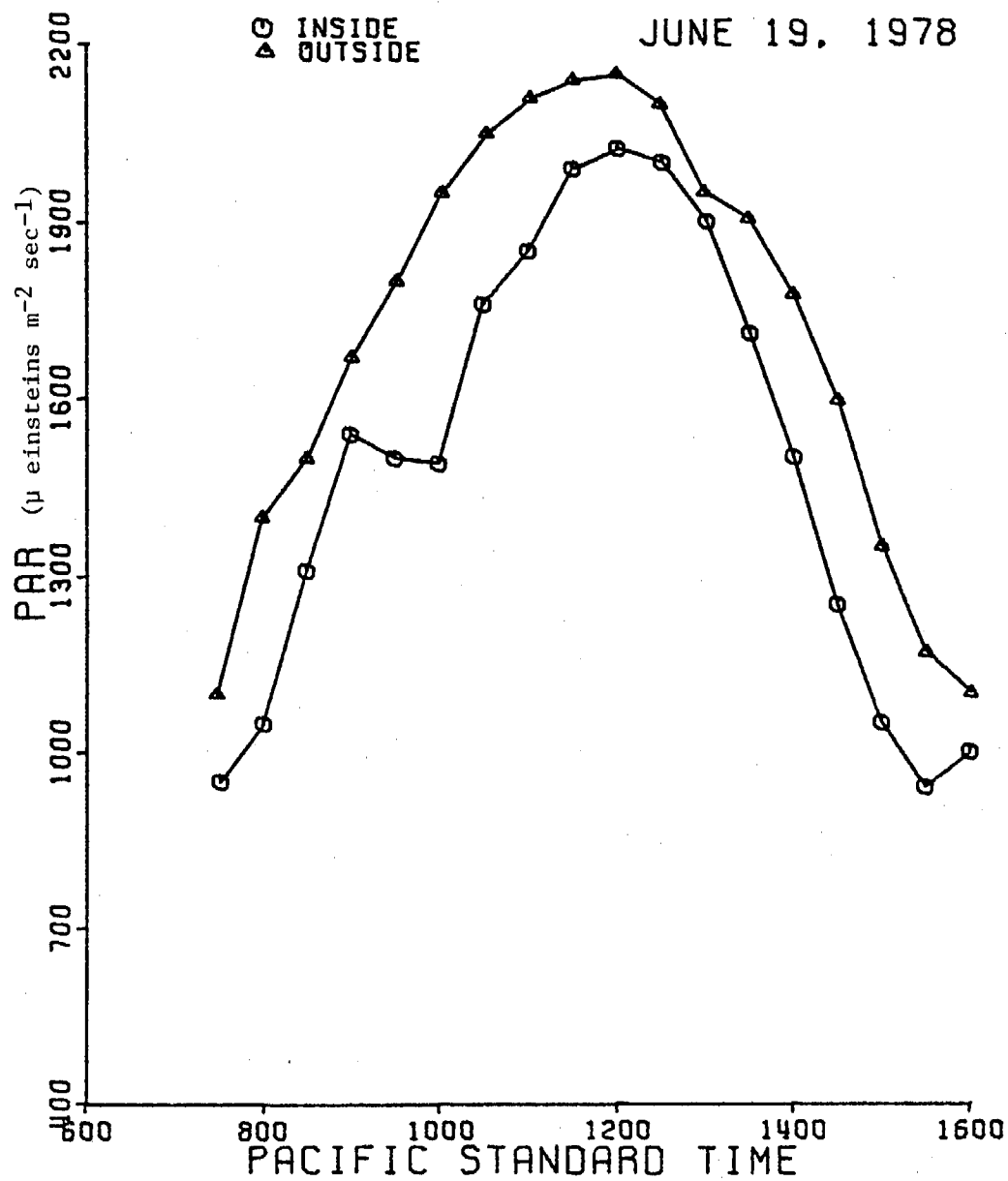


Figure 17. Comparison of Photosynthetically Active Radiation (PAR)
Curve for Chamber 2 with the Ambient Curve July 28, 1978

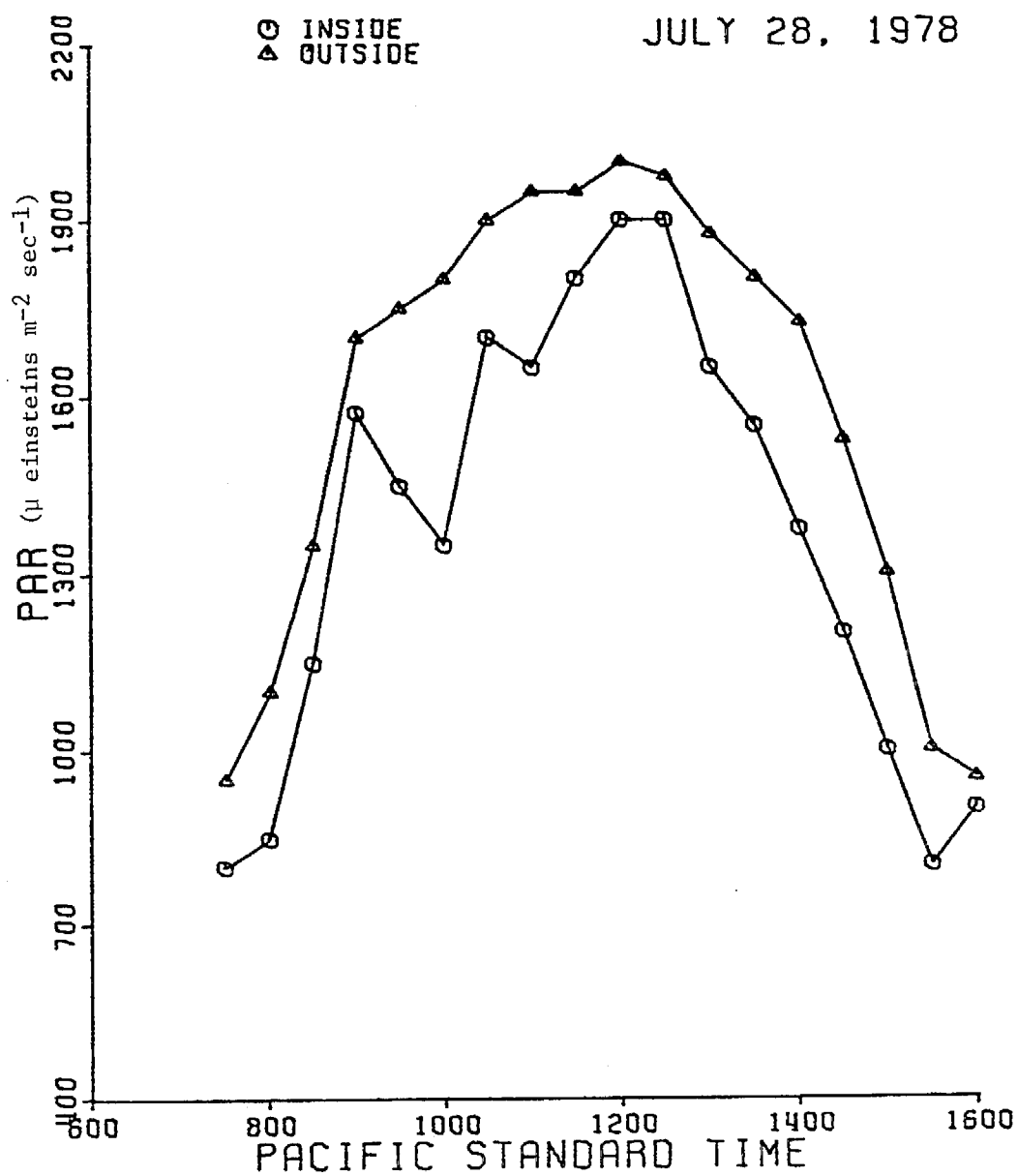


Figure 18. Comparison of Photosynthetically Active Radiation (PAR)
Curve for Chamber 2 with the Ambient Curve September 8, 1978

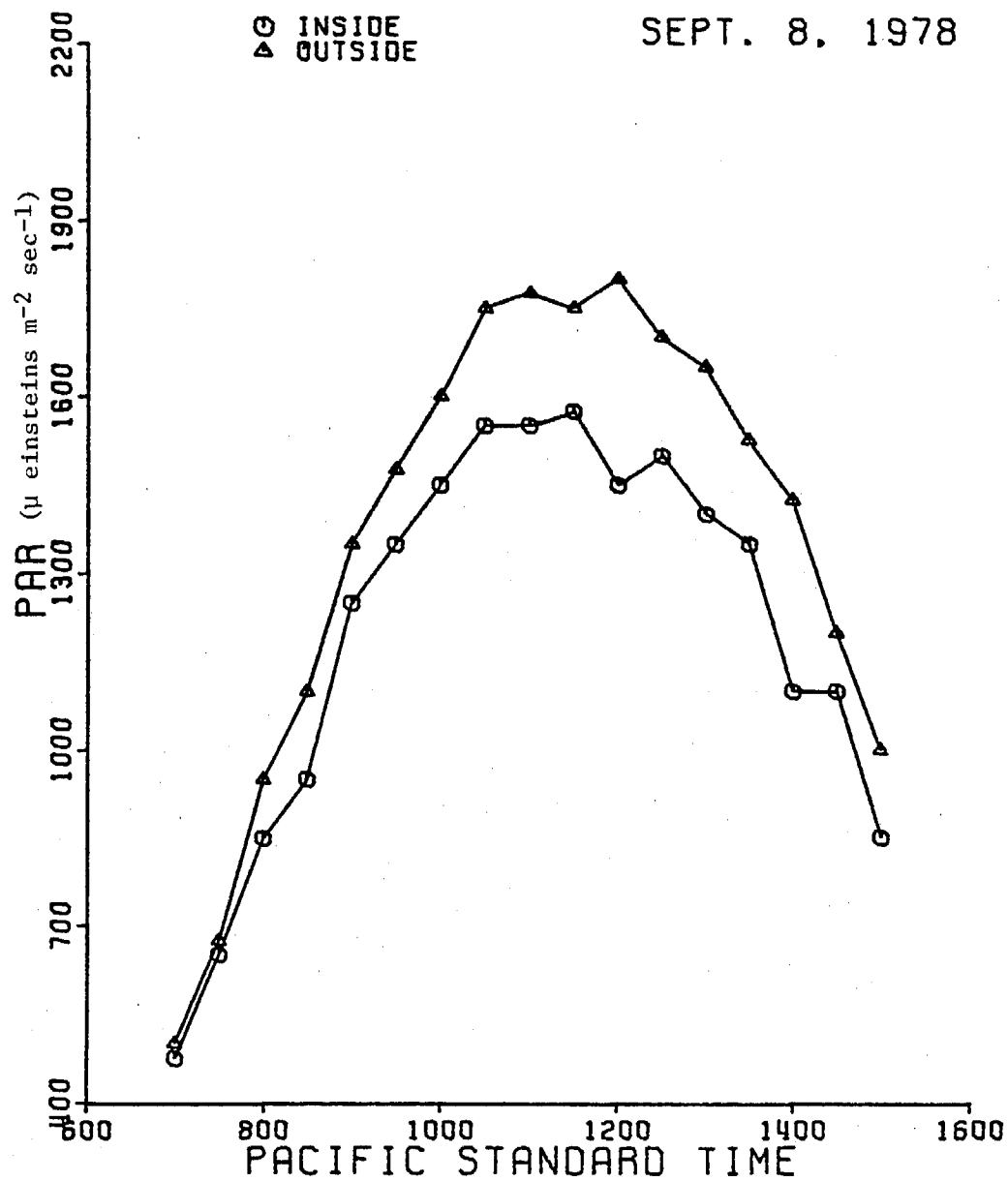


Table 16. Peak Chamber Ozone Concentrations (Highest One-Hour Average) with Corresponding Ambient Readings on Three Days During the Experiment when Ambient Oxidant (Ozone) was Highest

Chamber No.	% Carbon Filtered	6/17/78 ppm O ₃	7/13/78 ppm O ₃	7/14/78 ppm O ₃
1	75	.07	.07	.08
11	75	.06	.06	.07
2	75	.06	.06	.06
12	75	.07	.08	.08
3	100	.03	.03	.03
13	100	.03	.02	.03
4	50	.11	.10	.11
14	50	.11	.11	.12
5	50	.10	.09	.11
15	50	.11	.10	.11
6	75	.06	.05	.06
16	75	.07	.06	.07
7	100	.03	.03	.03
17	100	.03	.03	.03
8	50	.12	.13	.12
18	50	.11	.13	.12
9	25	.15	.17	.15
19	25	.14	.17	.15
10	100	.03	.03	.04
20	100	.03	.03	.03
Ambient	0	.27	.23	.28

Table 17. Analyses of Soil Placed in the 15-Gallon Containers before Tomatoes were Transplanted to the Chambers and of the Same Soil at the Termination of the Experiment

Parameter	Preplant	Post Harvest
Mn (ppm)	6.4	4.7
Fe (ppm)	14.0	16.0
Cu (ppm)	9.1	9.1
K (ppm)	660.0	628.0
SP ^a (%)	46	53
pH	5.9	6.8
EC _e (millimhos/cm)	1.30	0.81
P (ppm)	101.0	57.0
Zn (ppm)	6.3	8.3
Ca + Mg (me/l)	10.7	4.5
Na (me/l)	1.1	3.0
Cl (me/l)	1.9	1.8
B (ppm)	0.40	0.64
NO ₃ -N (ppm)	23.0	1.1

^a Saturation percentage - grams of water to saturate 100 grams of soil.

Table 18. Analysis of Water Soluble Sulfur as SO_4 in Soil Samples from Each of the Chambers and Two Ambient Air Plots. Two Samples of Soils not Used in the Experiment were Added as a Blank Test

Chamber No.	SO_4 (ppm)	Chamber No.	SO_4 (ppm)
1	100	7	20
11	65	17	55
2	130	8	10
12	35	18	45
3	225	9	20
13	25	19	20
4	165	Ambient 1	95
14	40	Ambient 2	35
5	75	Soil ^a 1	150
15	20	Soil 2	150
6	50		
16	30		

^aSoil - refers to non-utilized soil.

IV. DISCUSSION

Commercial yield, expressed as total weight of red and breaker tomato fruits, was significantly reduced when plants were exposed to 10 and 20 pphm SO_2 for six-hour periods on 27 days and 24-hour periods on 12 days during a 10-week fumigation experiment. No visible symptoms of SO_2 injury were detected during the fumigation. Although the addition of SO_2 to the treatments significantly reduced commercial yield, there was no differential in effect produced by 10 pphm SO_2 compared to the 20 pphm treatment. Regression analysis could not be used for the SO_2 treatments since there was no difference between effects from the 10 and 20 pphm treatments. Thus, only two varying points were available and regression analysis was not appropriate.

The absence of a difference in plant response to the two levels of SO_2 used in the experiment cannot be explained. The average number of red and breaker fruits was identical for the two levels of SO_2 and the difference in average weight was about 3.5%. There was no evidence of a synergistic response between the ambient oxidant and SO_2 ; therefore, it must be assumed that an increase from 4,500 pphm-hr to 9000 pphm-hr of SO_2 or an increase in concentration from 10 pphm to 20 pphm had no measurable effect on the tomato plants.

The 3 x 3 factorial design used for the Anova analysis for the combined SO_2 - O_3 experiment revealed a significant interaction between SO_2 and O_3 . The interaction occurred at a single treatment data point (4500 pphm-hrs SO_2 + 3243 pphm-hrs O_3) which corresponds to the 10 pphm SO_2 + 75% filtered to 25% nonfiltered ambient air chamber. The reason for the increased fruit weight was not apparent and was viewed with some degree of skepticism since

this data point did not appear to fit with the pattern of the other data points.

The results of the analyses of the numbers and weights of fruit in the red ripe, breaker and green categories provided no explanation for the tomato yield response to SO_2 - O_3 mixture. Red ripe fruit produced essentially the identical response as the commercial yield. Breaker fruit yield tended to produce an interactive response but this was actually an insignificant harvest variable because of the small number of fruit in the category. As indicated in the Results Section (p. 22), the green fruit variable did not respond to SO_2 , O_3 , or the interaction of these pollutants.

Sulfur dioxide treatment resulted in a slight but statistically significant difference in color intensity but these changes were well within the acceptable pulp color range for marketability. The interaction of ozone and SO_2 produced a slight but statistically significant change in pH of the fruits. Overall, the pH ranged from a low of 4.07 to a high of 4.30 and this difference is well within the commercially desirable range.

Regression analysis was run with data from the 3 x 3 factorial design plus the added data from two chambers which received 25% filtered to 75% nonfiltered ambient air and two plots in ambient air (not enclosed in chamber). This regression analysis proved to be unproductive in showing a relationship of the pollutant treatments largely because there was no differential in response within the ozone treatments and because the response to the 10 and 20 ppm SO_2 treatments was essentially identical. Yield response of both SO_2 treatments was significantly different from the no SO_2 treatment but the SO_2 treatments were not different from

each other. Regression analysis with only two significantly different points is inappropriate. A greater range in concentration of SO₂ and ozone (ambient oxidant), which would provide a range in plant yield and/or fruit quality response, should have produced data that could be used in regression analysis.

Response of plants in ambient air, measured as fruit size distribution, commercial yield, pulp color, weight and number of fruits in color categories and plant dry weight, was significantly different from that of plants in the filtered chambers. Although the reduced growth, yield and fruit quality may have been due entirely to the higher ozone level in the ambient air, it must be recognized that this treatment was not enclosed in chambers and much of the response may have been due to other unaccounted for environmental conditions or interactions. The "chamber effect" is well known in the research field and as yet attempts to entirely eliminate such effects have been unsuccessful. The ambient plots in this study produced significantly less fruit, lower fruit quality and less growth than the other ozone treatments. These data could not be used to evaluate chamber effects because of the absence of a 0% filtered to 100% nonfiltered ambient air treatment.

Environmental variables, soluble soil sulfate, and soil nutrients were monitored and these conditions were sufficiently uniform that it was concluded they should not have been a factor in altering yield responses of VF 145B-7879 processing tomatoes. Water soluble sulfate (SO₄) ranged from 10 ppm to 255 ppm in the soils from the various plots, but this variation is well within the allowable limits for good growth and production.

V. REFERENCES

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GLOSSARY

activated carbon, charcoal -- a powdered or granular carbon or charcoal prepared from wood, coconut shell, coal or petroleum and treated to increase porosity and enhance its capacity to remove oxidants, some organic vapors and other contaminants from air or liquids.

additive effects -- the combined effects of more than one pollutant acting simultaneously or in succession to give a total plant response equal to the sum of the independent effects.

air monitoring -- measurement of pollutant concentrations in the atmosphere.

ambient air -- air surrounding a given locus; the outside air.

antagonism -- when the combined effect of two or more pollutants is less than the sum of their independent effects; the antonym of synergism.

chronic injury -- injury which develops only after long-term or repeated exposure to an air pollutant, and expressed as chlorosis, bronzing, premature senescence, reduced growth etc.; can include necrosis.

damage -- a measure of the decrease in economic or aesthetic value resulting from plant injury by pollutants. (Term considered by some to be synonymous with injury.)

dose -- a measured concentration of a toxicant for a known duration of time (concentration per unit time) to which a receptor is exposed.

fumigation -- the natural or controlled exposure of plants to toxic gases or volatile substances.

injury -- any change in the appearance and/or function of a plant that is deleterious to the plant.

monitoring -- the use of gas sensing instruments or other devices to measure the concentrations of pollutants.

oxidant -- a substance capable of oxidizing a reference substance, that substance itself incapable of being oxidized by atmospheric oxygen; refers to several oxidizing gases in the atmosphere, particularly ozone, nitrogen dioxide and peroxyacetyl nitrates (PAN); those compounds capable of liberating iodine from neutral buffered potassium iodide solutions.

ozone -- the triatomic (O_3) allotrope of oxygen; a colorless to faintly bluish, unstable, pungent gas produced by electrical discharge in air, by solar ultra-violet radiation, or by other photochemical reactions of mixtures of certain hydrocarbons and NO_x ; a strong oxidizing agent that is phytotoxic at low concentrations.

phytotoxicant -- any agent that becomes toxic to plants.

pollutant (air) -- any gas, liquid or solid air contaminant that causes undesirable effects on living organisms or materials.

pphm -- parts by weight or volume of pollutant per hundred million parts by volume of air. (Usually refers to volume of pollutant if not so stated.)

sensitivity -- a physiological condition of susceptible plants, or particular plant tissues, whereby they are prone to injury by pollutants.

synergism -- when the combined effect of two or more independent treatments is greater than the sum of each treatment alone. (Definition considered by some to be that of potentiation.)

APPENDIX A

Chamber Temperature Data for June 22,
June 23 and June 24, 1978

Description of Data	TEMPERATURE
Date	JUNE 22, 1938

Description of Data TEMPERATURE
Date JUNE 23, 1928

1978 ARB Data Summary Log

[illegible]

28

Description of Data	Temperature
Date	June 23, 1978

Description of Data	Temperature
Date	June 23, 1978

1978 ARB Data Summary Log

[illegible]

38

APPENDIX B

Chamber Relative Humidity Data Between
June 19, 1978 and July 31, 1978.

Locations: West Exhaust, East Exhaust,
Chamber 4 Exhaust, Chamber 13 Exhaust.

LOCATION JULIAN DATE

01 02 03 04 05 06 07 08 09 10 11 12 13 14 15 16 17 18 19 20 21

WEST EXH 1708	23	24	23	35	30	22	30	25	16	12	9	4	7	11	14	21	18	20	17	25	30
WEST EXH 1718	34	34	40	39	43	43	37	30	36	29	26	17	12	10	17	25	20	23	11	31	38
WEST EXH 1728	41	40	49	49	46	43	42	38	35	19	22	18	14	12	10	6	10	15	20	22	28
WEST EXH 1738	44	41	50	53	57	33	41	37	35	26	5	10	13	9	10	14	10	13	21	27	36
WEST EXH 1748	43	50	50	51	43	48	31	27	27	20	15	10	8	10	13	12	15	18	20	22	15
WEST EXH 1758	23	23	24	21	21	33	27	25	28	17	7	6	6	12	7	9	11	14	20	26	10
WEST EXH 1768	35	31	44	43	43	43	42	38	31	31	30	26	27	20	23	25	27	30	34	36	38
WEST EXH 1778	54	62	61	61	66	66	62	55	50	41	42	40	30	35	35	35	40	45	51	52	59
WEST EXH 1788	67	62	62	62	62	62	57	49	44	48	38	36	34	35	35	39	42	44	52	51	54
WEST EXH 1798	66	66	66	66	66	66	66	66	66	66	66	66	66	66	66	66	66	66	66	66	66
WEST EXH 1808	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
WEST EXH 1818	66	66	71	71	71	71	68	61	54	52	47	44	39	43	40	43	34	39	40	47	53
WEST EXH 1828	59	62	67	71	66	71	65	61	52	50	44	45	41	38	38	34	53	33	40	47	48
WEST EXH 1838	62	66	66	65	70	70	68	60	61	52	45	41	39	38	40	39	36	38	42	47	56
WEST EXH 1848	66	61	66	65	65	70	57	60	54	55	53	47	45	46	44	41	33	35	33	39	41
WEST EXH 1858	57	57	66	57	61	50	59	57	50	56	44	45	42	40	41	41	45	48	50	51	57
WEST EXH 1868	67	67	72	72	77	75	73	69	70	63	60	53	54	49	44	50	34	38	46	51	53
WEST EXH 1878	67	68	67	77	72	77	64	65	62	57	86	56	53	52	52	52	58	39	40	44	35
WEST EXH 1888	68	68	67	72	72	77	73	69	63	60	58	56	54	0	62	60	59	62	64	70	69
WEST EXH 1898	80	75	79	79	83	33	75	77	70	63	61	62	60	1	1	1	1	1	27	40	41
WEST EXH 1908	61	65	60	64	68	73	65	55	53	36	32	24	14	22	14	14	7	14	26	34	41
WEST EXH 1918	59	64	68	67	72	77	68	61	52	43	45	39	22	16	26	24	27	27	30	35	39
WEST EXH 1928	64	78	78	77	82	82	83	69	66	56	53	48	35	30	30	21	23	24	30	39	44
WEST EXH 1938	64	64	63	63	72	72	60	47	39	38	31	18	13	16	20	15	20	25	30	35	38
WEST EXH 1948	26	39	32	35	39	42	36	27	30	23	12	11	7	7	15	17	21	24	26	29	31
WEST EXH 1958	31	35	36	33	38	41	42	34	28	26	22	21	18	18	18	22	25	28	26	31	32
WEST EXH 1968	32	35	37	39	44	47	39	29	31	30	25	24	20	22	28	27	30	29	28	37	38
WEST EXH 1978	47	53	50	52	60	53	54	49	48	39	37	39	31	31	31	33	37	38	41	49	51
WEST EXH 1988	63	67	49	75	75	75	68	58	50	46	42	38	34	37	41	46	50	49	53	62	64
WEST EXH 1998	80	75	75	79	79	81	71	65	56	50	46	45	40	41	39	41	45	41	45	52	61
WEST EXH 2008	75	79	79	79	79	79	75	68	62	0	54	42	37	43	35	41	37	42	43	46	51
WEST EXH 2018	58	100	65	74	65	69	59	53	49	53	46	43	37	38	39	38	35	35	40	52	58
WEST EXH 2028	66	70	74	74	73	73	66	61	59	51	41	35	36	44	43	43	47	52	60	66	65
WEST EXH 2038	80	79	79	84	79	81	71	61	59	57	52	48	43	46	46	45	48	47	52	55	61
WEST EXH 2048	71	71	75	70	79	71	68	65	60	55	51	49	42	43	51	55	53	54	55	57	63
WEST EXH 2058	72	76	76	76	76	75	76	76	70	58	53	51	52	55	49	50	58	57	59	64	67
WEST EXH 2068	76	81	80	80	80	83	76	73	74	64	59	54	58	55	55	53	58	60	65	71	74
WEST EXH 2078	76	76	76	76	80	76	73	66	64	62	59	57	58	53	58	58	58	60	65	68	70
WEST EXH 2088	76	76	80	76	76	75	77	73	71	72	66	64	61	62	59	62	61	61	66	68	71
WEST EXH 2098	77	76	85	85	80	80	77	74	71	66	60	64	64	59	59	62	64	70	69	75	74
WEST EXH 2108	85	81	85	85	85	84	76	81	74	68	69	60	67	58	58	61	64	63	66	79	76
WEST EXH 2118	85	85	85	89	89	89	80	77	70	71	68	63	55	56	62	71	67	70	45	82	82
WEST EXH 2128	90	95	84	89	84	84	84	73	74	75	100	67	64	70	67	67	69	69	75	78	78

LOCATION	JULIAN DATE	HOUR																							
		01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21			
EAST EXH 1708	14	13	18	22	18	15	21	22	16	12	9	6	7	10	13	21	18	17	17	18	26				
EAST EXH 1718	28	27	30	28	33	33	32	28	35	31	30	16	13	10	17	22	19	20	9	26	31				
EAST EXH 1728	31	30	33	36	32	33	33	40	33	23	27	22	19	14	12	9	14	13	20	18	20				
EAST EXH 1738	28	35	37	35	38	39	41	36	35	26	10	14	11	14	12	14	13	14	20	21	24				
EAST EXH 1748	31	34	37	37	30	30	32	32	28	22	14	14	10	10	15	13	17	18	19	20	9				
EAST EXH 1758	11	13	11	13	17	16	26	23	26	20	11	6	9	14	7	10	11	14	16	19	22				
EAST EXH 1768	20	25	27	28	28	28	31	33	33	31	31	26	23	20	22	22	24	25	28	26	29				
EAST EXH 1778	39	37	40	44	43	48	48	54	52	43	44	39	36	37	35	35	37	39	41	42	44				
EAST EXH 1788	46	49	49	49	49	49	45	41	43	44	38	42	39	37	38	39	38	44	41	44	46				
EAST EXH 1798	52	52	52	57	47	0	0	0	54	47	45	41	42	44	38	35	35	37	43	45	47				
EAST EXH 1808	0	0	0	0	0	0	0	0	0	52	50	44	42	43	37	35	37	36	35	32	45				
EAST EXH 1818	49	53	52	57	51	55	58	59	57	51	24	43	40	39	25	33	30	29	34	34	36				
EAST EXH 1828	46	45	50	44	52	52	55	56	50	44	42	36	29	30	30	21	35	23	21	27	27				
EAST EXH 1838	40	48	43	42	46	45	52	50	52	45	39	35	30	26	24	24	18	19	23	30	31				
EAST EXH 1848	36	39	39	38	36	35	38	46	44	38	40	35	30	35	33	30	39	31	30	34	32				
EAST EXH 1858	38	40	39	44	43	43	49	46	45	43	37	35	34	35	33	28	30	31	30	30	39				
EAST EXH 1868	46	45	49	53	57	57	58	59	60	53	50	41	42	31	26	27	30	35	36	37	36				
EAST EXH 1878	42	50	54	53	49	57	54	55	53	51	75	40	35	34	30	32	38	33	31	35	36				
EAST EXH 1888	52	51	50	58	53	57	63	64	57	51	46	44	39	0	36	37	31	32	34	38	40				
EAST EXH 1898	46	45	45	52	51	55	57	42	52	40	39	37	25	20	26	26	27	24	28	32	33				
EAST EXH 1908	45	45	48	44	52	51	52	54	52	47	39	29	20	30	17	17	8	14	27	29	30				
EAST EXH 1918	41	44	47	46	40	49	55	52	54	48	47	41	27	24	34	28	28	27	30	28	31				
EAST EXH 1928	49	47	51	54	58	52	63	64	61	58	57	47	42	37	35	28	28	27	31	37	38				
EAST EXH 1938	45	44	43	42	50	42	47	45	44	40	35	32	30	38	39	34	39	38	39	36	34				
EAST EXH 1948	25	27	31	33	34	33	38	41	44	43	31	36	33	39	46	48	47	43	40	39	33				
EAST EXH 1958	36	36	35	37	36	40	46	48	50	49	45	41	40	46	44	47	46	46	41	41	42				
EAST EXH 1968	39	39	42	41	40	42	45	47	49	48	46	42	41	45	48	45	49	46	45	42	43				
EAST EXH 1978	43	45	47	43	50	45	50	55	56	55	53	52	53	51	51	51	47	49	48	45	43				
EAST EXH 1988	46	48	29	47	50	54	52	53	59	57	55	54	51	49	55	54	54	53	51	52	47				
EAST EXH 1998	51	54	54	54	53	57	58	56	61	56	57	55	56	57	51	52	54	47	48	49	52				
EAST EXH 2008	51	50	50	57	57	52	62	59	61	0	57	54	53	57	54	55	51	54	49	47	49				
EAST EXH 2018	48	100	45	49	50	49	50	52	58	56	57	56	51	57	55	55	55	54	53	57	49				
EAST EXH 2028	47	46	41	45	44	52	50	56	58	56	52	60	55	61	61	57	57	62	58	56	51				
EAST EXH 2038	54	54	54	52	52	56	53	60	65	63	64	64	59	60	60	60	57	56	58	53	55				
EAST EXH 2048	52	52	54	50	45	53	58	60	66	64	62	60	61	65	68	65	64	63	56	54	53				
EAST EXH 2058	53	53	52	52	52	51	51	60	61	63	61	59	63	64	61	61	64	63	59	54	53				
EAST EXH 2068	53	52	52	55	54	54	59	61	62	63	61	59	63	64	61	61	61	58	57	55	53				
EAST EXH 2078	53	52	52	52	55	55	56	57	63	64	62	60	60	64	64	64	61	58	57	59	54				
EAST EXH 2088	46	48	48	52	48	51	56	57	62	60	65	60	63	61	62	62	62	58	56	54	54				
EAST EXH 2098	50	53	52	52	52	55	60	61	63	64	62	60	64	61	61	61	58	61	57	59	57				
EAST EXH 2108	49	52	52	52	54	54	55	60	62	60	58	62	60	60	55	55	55	54	56	54	52				
EAST EXH 2118	48	51	54	54	53	57	54	58	52	59	57	58	53	55	58	58	57	56	35	56	52				
EAST EXH 2128	51	50	54	54	52	54	54	54	54	54	54	54	54	54	54	54	54	54	54	54	54				

LOCATION JULIAN DATE

CH 4 EXH 1708
CH 4 EXH 1718
CH 4 EXH 1728
CH 4 EXH 1738
CH 4 EXH 1748
CH 4 EXH 1758
CH 4 EXH 1768
CH 4 EXH 1778
CH 4 EXH 1788
CH 4 EXH 1798
CH 4 EXH 1808
CH 4 EXH 1818
CH 4 EXH 1828
CH 4 EXH 1838
CH 4 EXH 1848
CH 4 EXH 1858
CH 4 EXH 1868
CH 4 EXH 1878
CH 4 EXH 1888
CH 4 EXH 1898
CH 4 EXH 1908
CH 4 EXH 1918
CH 4 EXH 1928
CH 4 EXH 1938
CH 4 EXH 1948
CH 4 EXH 1958
CH 4 EXH 1968
CH 4 EXH 1978
CH 4 EXH 1988
CH 4 EXH 1998
CH 4 EXH 2008
CH 4 EXH 2018
CH 4 EXH 2028
CH 4 EXH 2038
CH 4 EXH 2048
CH 4 EXH 2058
CH 4 EXH 2068
CH 4 EXH 2078
CH 4 EXH 2088
CH 4 EXH 2098
CH 4 EXH 2108
CH 4 EXH 2118

01 02 03 04 05 06 07 08 09 10 11 12 13 14 15 16 17 18 19 20 21

23	32	30	35	34	27	31	23	18	15	13	8	11	17	18	21	22	24	22	26	34
38	45	45	44	48	44	37	32	31	28	26	18	15	16	18	23	22	23	12	32	36
41	44	43	46	50	49	46	40	32	22	25	21	18	19	14	13	17	21	25	26	31
48	48	51	54	53	54	45	42	36	31	14	18	17	18	19	20	18	21	27	57	38
44	47	51	51	43	43	32	33	32	23	18	18	15	23	18	19	22	23	26	28	18
24	26	25	28	28	34	30	29	30	21	15	11	14	21	14	14	18	21	26	30	11
36	38	45	48	48	43	43	35	39	32	32	26	25	29	25	29	30	30	38	41	42
59	57	62	66	66	71	62	61	48	35	40	45	37	39	40	38	59	54	63	66	69
68	73	72	72	72	72	67	64	54	58	50	45	43	51	47	46	58	57	62	65	68
77	72	72	77	77	77	0	0	65	55	53	51	49	54	50	46	55	53	59	61	69
0	0	0	0	0	0	0	0	0	56	51	49	47	55	51	47	53	48	52	50	61
77	72	77	82	76	75	73	66	60	54	53	50	48	56	46	45	44	46	47	51	57
68	67	67	72	71	73	69	66	60	55	49	45	45	53	43	38	51	36	35	43	48
66	71	71	70	70	76	67	61	58	53	45	43	38	47	42	41	37	35	38	46	52
62	61	66	70	70	73	62	56	54	49	47	43	44	55	51	47	53	48	46	51	50
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LOCATION JULIAN DATE

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